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Geological History of a Holocene Drainage System: Hack Creek, Virginia

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GEOLOGICAL HISTORY OF A HOLOCENE DRAINAGE SYSTEM

HACK CREEK, VIRGINIA

A Thesis

Presented to

The Faculty of the School of Marine Science

The College of William and Mary in Virginia

In Partial Fulfillment

of the Requirements for the Degree of

Master of Arts

by

Robert A. Gammisch

1986

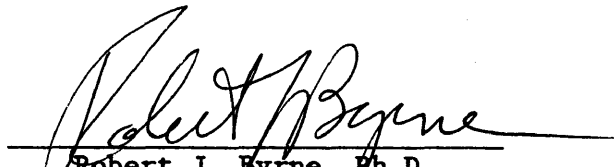
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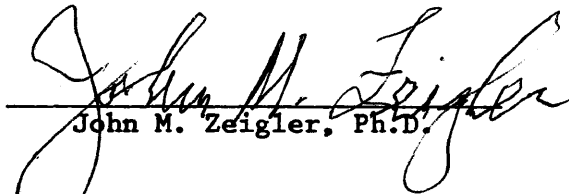
This thesis is submitted in partial fulfillment of the requirements
for the degree of

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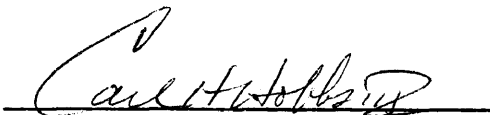

Carl H. Hobbs, III, M.S.

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DEDICATION

I dedicate this work to my wife, Susan, and my daughter, Amanda,
for their years of support and sacrifice during this project.

ACKNOWLEDGEMENTS

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I also thank the graduate students and technical staff members, many of whom have come and gone since the beginning of this research, for their untold help in the field and laboratory.

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ABSTRACT

Hack Creek, a minor inlet-basin drainage system associated with the Potomac River Estuary, is typical of drainage systems found throughout the Virginia Coastal Plain. It is postulated that the sub-estuaries (second or third order tributaries), minor inlet basins, and ephemeral pond systems are evolutionary stages of fluvial drainage systems drowned during a transgression and developed in response to valley cuts during regression of the sea. Hack Creek, as it exists today, represents the middle or second stage of evolution during the ensuing marine transgression.

A sub-bottom, seismic reflection survey completed in 1985 delineated a complex paleochannel system adjacent to Hack Creek and the three ephemeral ponds to the east and west of Hack Creek's inlet. These paleochannels proved to be the remains of a dendritic drainage system contiguous with the active drainage of the study area and tributary to the ancestral Potomac River. The survey also located three large paleochannels adjacent to Hack Creek which can be associated with the ancestral Potomac River. The Hack Creek paleochannel complex is located inshore of two of the Potomac River paleochannels and is underlain in part by the third. Superposition of the Hack Creek paleochannel system and the shoreline formations indicate the third Potomac River paleochannel (previously unreported) to be pre-Tabb (late Pleistocene), or older in age. The sub-bottom seismic survey data indicate that none of the Hack Creek paleochannels terminate in or near the pre-Tabb channel. Vibracore data within the study area verified that the Hack Creek drainage system incised into the formations of the Chesapeake Group during its fluvial phase and terminated in the Potomac River paleochannel 4 km offshore of the present Hack Creek inlet. The entire system displays only one gradational succession of sediments, those deposited during the late Pleistocene and Holocene regressive-transgressive cycle. These data validate that Hack Creek and its associated drainage systems are of late Pleistocene origin. Thus a continuous geologic history of Hack Creek is preserved in the sedimentary record, which can be utilized to define the evolution of other Holocene drainage systems.

GEOLOGICAL HISTORY OF A HOLOCENE DRAINAGE SYSTEM

HACK CREEK, VIRGINIA

INTRODUCTION

General Statement

The purpose of this study is to determine the geologic history of a Holocene, tidal-creek system. Hack Creek, a brackish-water estuary, is a classic example of a drowned primary drainage system exemplifying the active drainage of the Virginia Coastal Plain (Figure 1). The principal questions addressed in this study are when did a drainage first develop and what evolutionary phase does the present system represent.

Hundreds of kilometers of sub-bottom profile tracks have been collected in the Chesapeake Bay and its tributaries. The courses of paleodrainage for the major rivers in the Chesapeake Bay have been established, and the fact that the present Chesapeake Bay and its tributaries are the drowned valleys of the Susquehanna and other rivers active during the late Pleistocene regression of sea level is accepted (Ryan, 1952; Hack, 1957; Harrison et al., 1965; Schubel and Zabawa, 1972; Meisburger, 1972; Mixon, personal communication, 1978; Carron, 1979; Knebel et al., 1981). However, the age of the system and the number of transgressive-regressive cycles in the sedimentary record is still in question. Colman et al. (in prep.) found multiple events of channel downcutting and filling in the Maryland portion of the Chesapeake Bay. Seismic reflection records in the lower Virginia portion of the Bay revealed a marked absence of the same feature. The

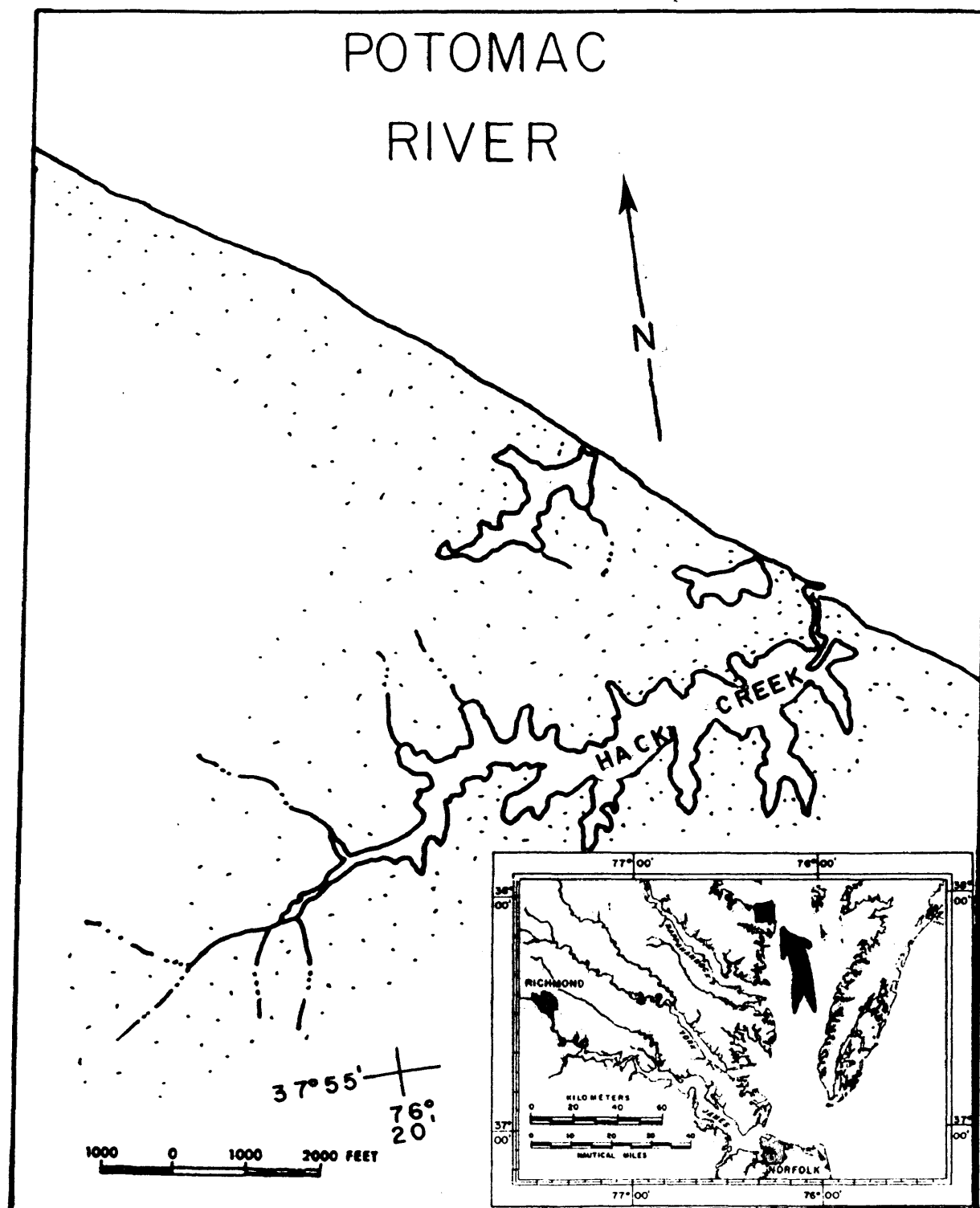


Figure 1. Location map showing Hack Creek and environs (from Burgess 7.5 minute quadrangle).

conclusion derived was that the upper and lower Chesapeake Bay might be of different ages. Carron (1979) stated "The major Virginia rivers (Rappahannock, Piankatank, York, and James) were not tributary to the Susquehanna in the present Chesapeake Bay region during the Wisconsin Glaciation." He also concluded that the Potomac River was a tributary of the Susquehanna River which at that time occupied the region of Tangier Sound.

The sub-bottom data of previous investigators indicated a complex system of minor paleochannels throughout the Chesapeake Bay and its tributaries. Most of these channels have been identified as the fluvial remnants of upland drainage. There is no conclusive evidence in the literature that these channels are contiguous with the present upland drainage or that they are truly associated with the paleodrainage of the major river systems. Research associated with drainage systems has been restricted to the major rivers. The availability of data regarding the geologic history of the Potomac River, the structure of the fastlands typical of the Virginia Coastal Plain, and the size of the Hack Creek drainage basin, which is large enough to be associated with all the upland formations, makes this study area a source of data to unravel the geologic history of a drainage system.

In the Chesapeake-Potomac estuary there are three sub-systems that can be identified with fastland drainage. Byrne et al. (1980) examined many of these systems to develop a relationship between inlet throat area and tidal prism, but did not address the development and evolution of these systems. The first type are small tributaries of the major

rivers, with little or no restriction to flow at the entrance. The tidal range of this type of system is the same inside and outside the throat. These systems tend to be large, greater than 400 hectares of surface area, and have a dendritic shape with steep valley walls and narrow valley floors. The bathymetry of these systems usually express a distinct channel thalweg, which suggests tidal currents effected sedimentation (Figure 2).

The second type of sub-system, the inlet-basin system (Figure 3), has a restricted entrance and the inlets often have a tidal delta. Whether this delta is ebb tidal or flood tidal depends on the system's hydrodynamic characteristics. The tide inside these systems frequently displays a phase lag with a reduced tidal range (Figure 4). The valley walls of these systems are steep but the valley floor is flat with no channels expressed in the bathymetry. These systems are also dendritic in shape.

The third type of system is the ephemeral tidal basin or pond (Figure 5). This system does not have sufficient basin size to allow tidal flux to prevent longshore movement of sand from closing the inlet during periods of low runoff. Thus the system will open and close in response to its fluvial drainages. During periods of high rainfall or storm surge, the system floods. When the hydraulic head is sufficient, an inlet will break open and a channel will be cut through the beach into the adjacent tributary. The system will again become tidal until equilibrium is achieved (Figure 6). The interior basins of these systems are small, generally less than 40 hectares, thus the tidal prism

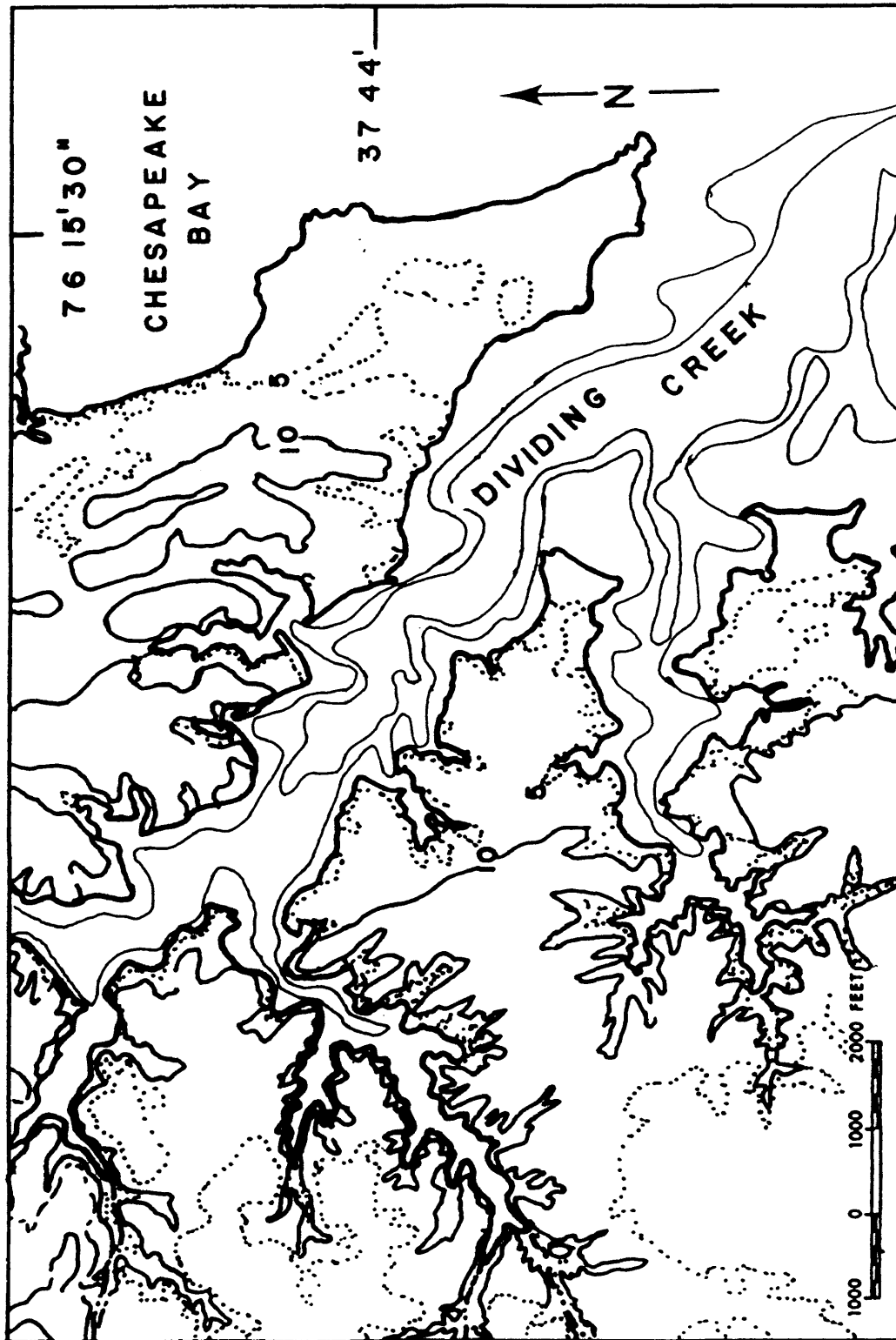


Figure 2. Example of a Type 1 drainage system as exemplified by Dividing Creek, Virginia (from Fleets Bay 7.5 minute quadrangle).

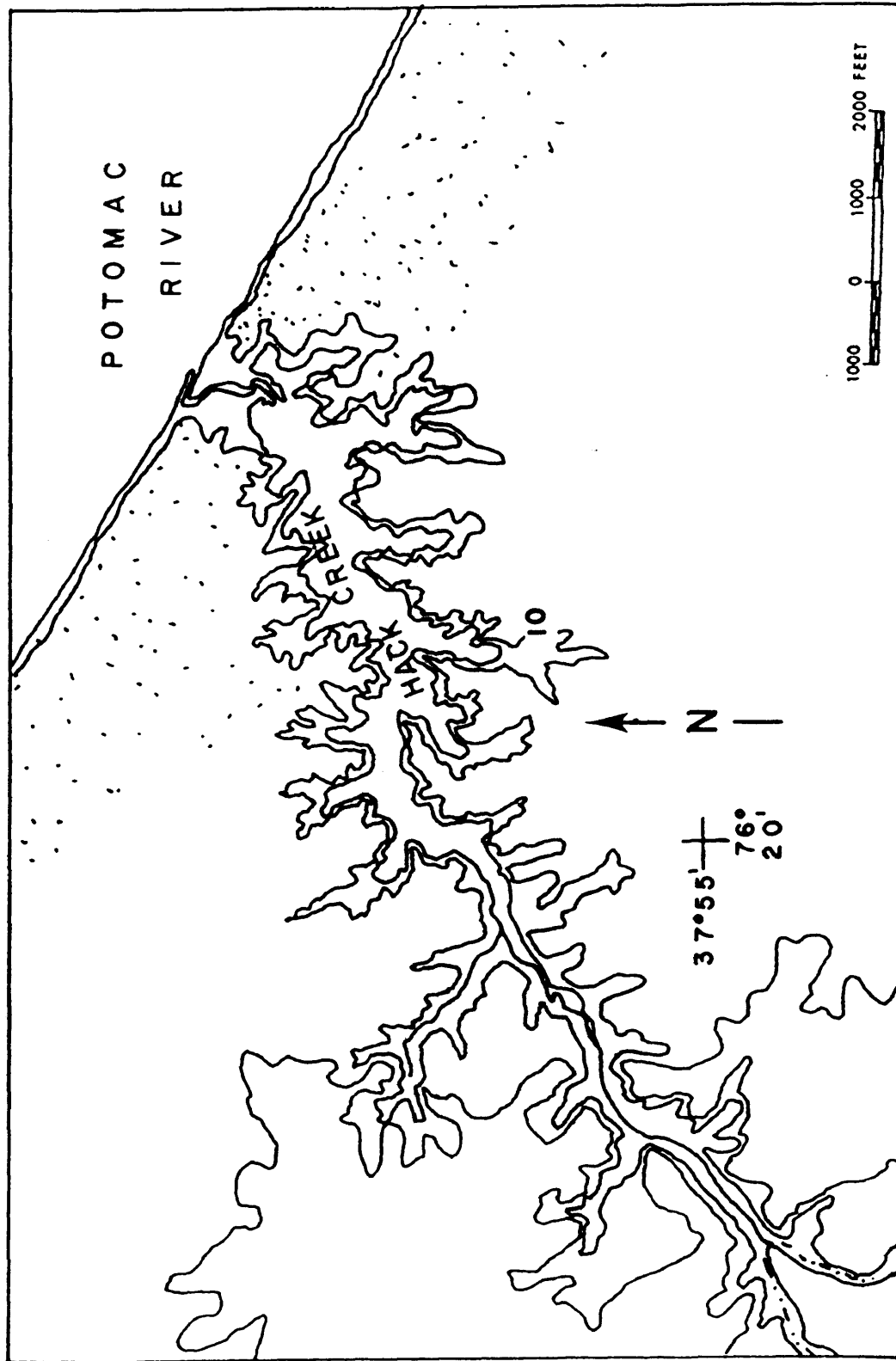


Figure 3. Example of a Type 2 drainage system as exemplified by Hack Creek, Virginia (from Burgess 7.5 minute quadrangle).

HACK CREEK (NLBUR 03) 17 MAY 1978

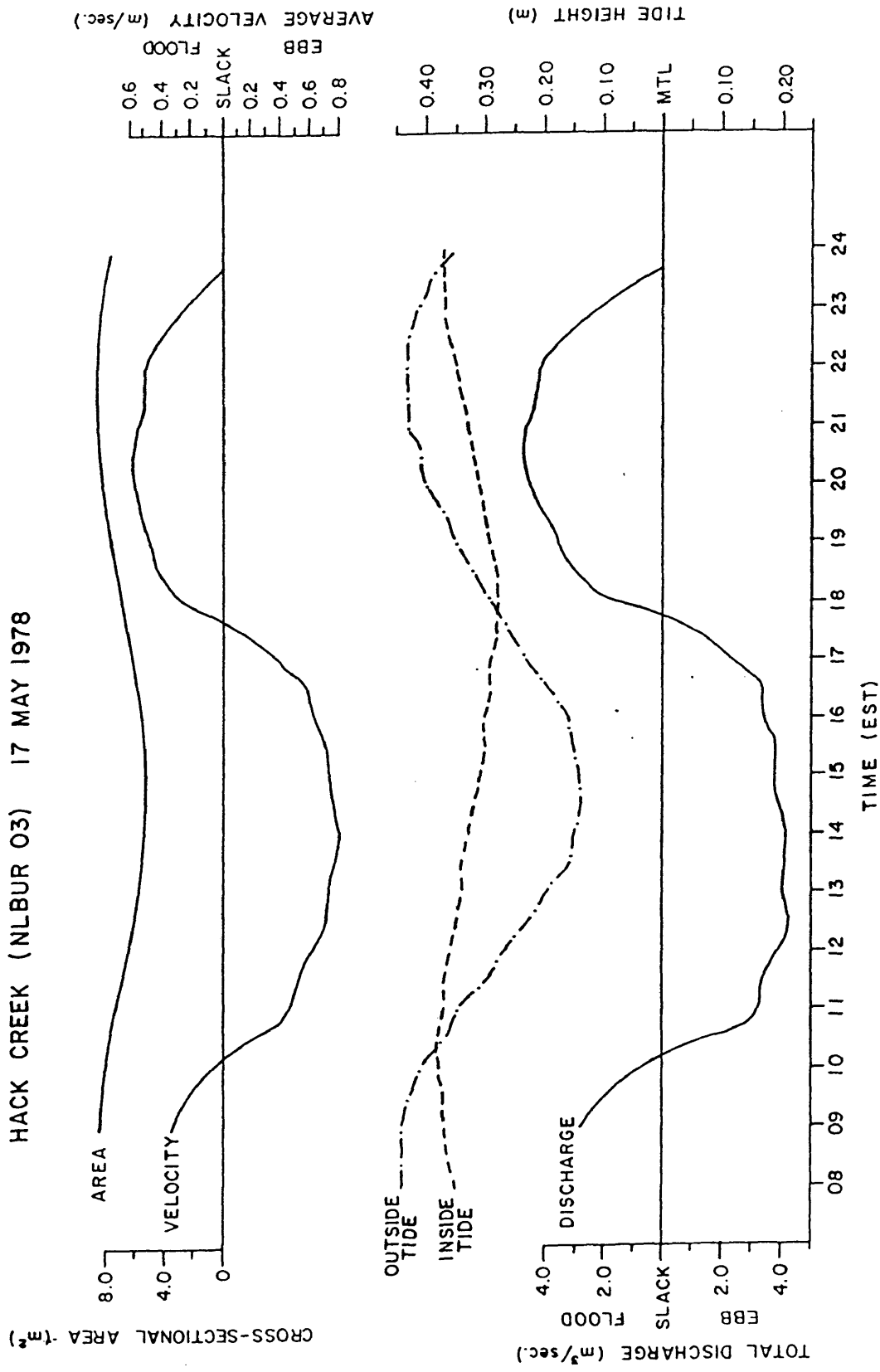


Figure 4. Tidal characteristics and discharge of a Type 2 drainage system.

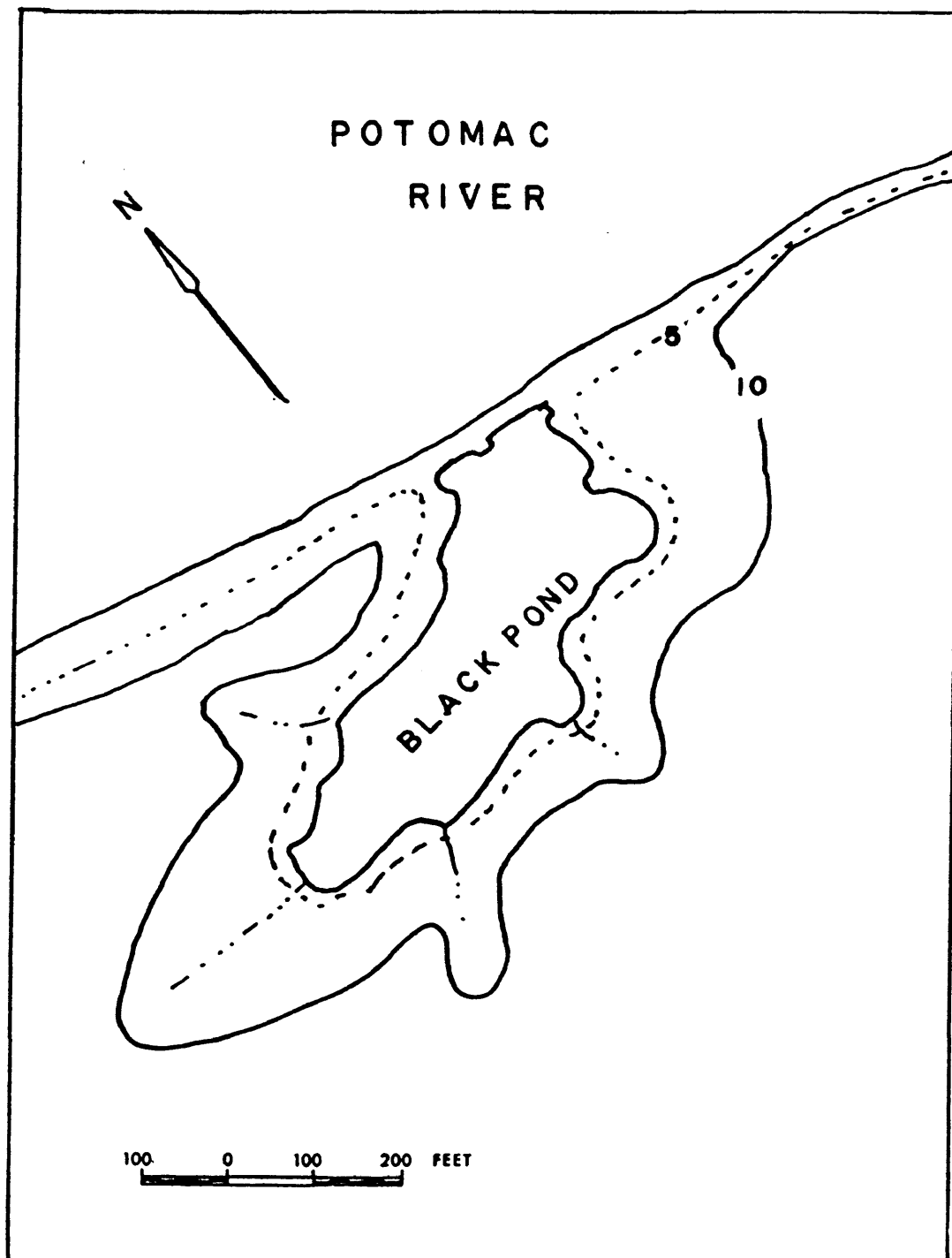


Figure 5. Example of a Type 3 drainage system as exemplified by Black Pond, Virginia (from Burgess 7.5 minute quadrangle).

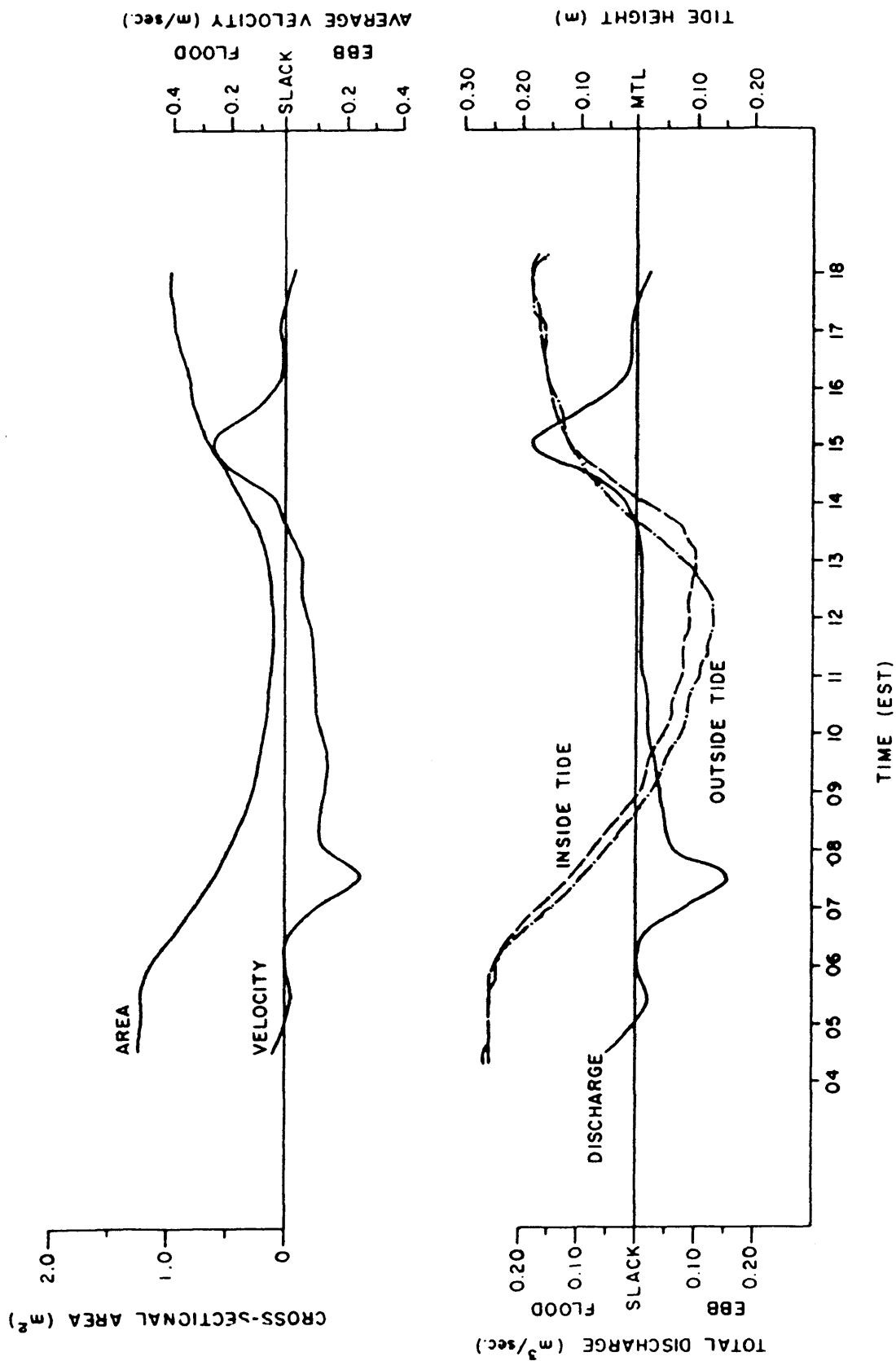


Figure 6. Tidal characteristics and discharge of a Type 3 drainage system during an open phase.

is small and the inlet will soon become choked with sand, the system will close and once again become a pond.

The three types of drainage systems appear to be evolutionary stages of tidally influenced stream valleys. Peebles (1984) developed a conceptual model for stream valleys during a marine transgression. While the model addresses the depositional sequences and environments that tend to migrate upstream with a rise in sea level, it does not explain the three types of drainage observed in the Potomac-Chesapeake estuary.

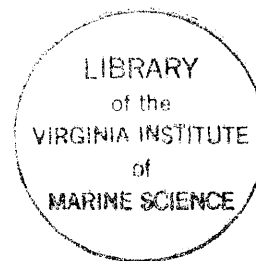
Hypothesis

This study tests the hypothesis that subaerial drainage channels from both primary and secondary fluvial systems are cut into Quaternary and Tertiary sediments during successive falls in sea level, and filled by both fluvial and estuarine sediment processes during subsequent rises of sea level during the Pleistocene and Holocene, thus preserving the geologic history of both the major and minor channels in the sedimentary record.

Objectives

The primary objective in this study is to delineate a fluvial drainage-channel-complex associated with the fastland drainage of Hack Creek and to determine if that drainage was contiguous with a major river system of the Potomac-Chesapeake estuary during a lower stand of sea level. The second objective is to trace the geologic history of the

Hack Creek drainage system, and to determine its age and development, using the sedimentary sequences.



METHODOLOGY

Sub-bottom Survey

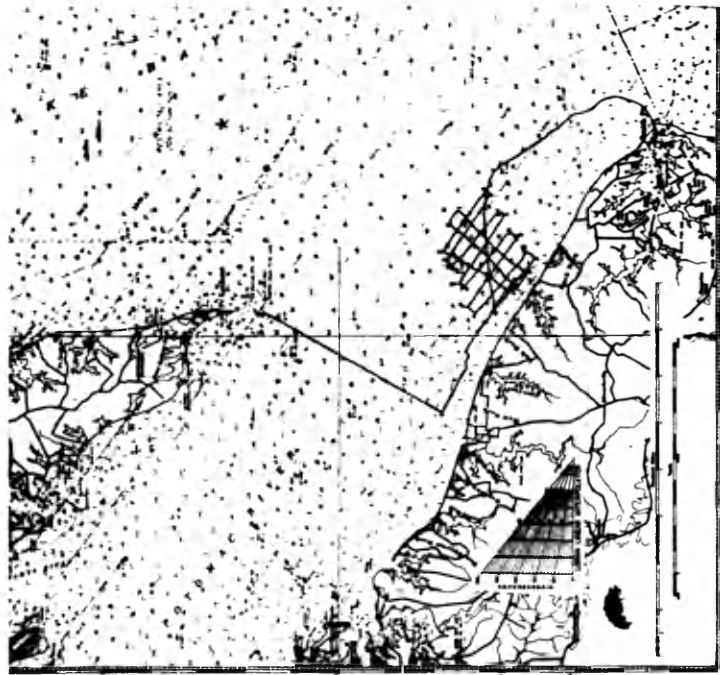
A Raytheon Model RTT-1000 sub-bottom survey system was employed to survey the paleodrainage system between Hack Creek and the Potomac River thalweg. The Raytheon is a two channel system that displays both the present bathymetry and the sub-bottom horizons on a DE 719 Recorder (Figure 7). This is achieved through the use of one, high frequency (200 kHz) transducer to delineate the water sediment interface (present bottom) and a low power (2,000 watts), low frequency (7 kHz) transducer to delineate sub-bottom stratigraphic units. The profiler was used in conjunction with a Northstar LORAN-C Positioning System coupled to an X-Y Coordinate Plotter and LORAN printer. This allowed every fix mark on the recorder to be accurately plotted (within 20 m) on a NOAA nautical chart with LORAN-C overprint (Figure 8).

The survey was conducted in the spring of 1979, while water temperature was below 10°C to avoid masking by gas accumulation in the sediment. Gas tends to diffuse the acoustical signal and mask the reflection record.

Additional track lines were run in the fall of 1985. The purpose of this survey was to further define stratigraphy and morphological units delineated in the first survey (Figure 9).

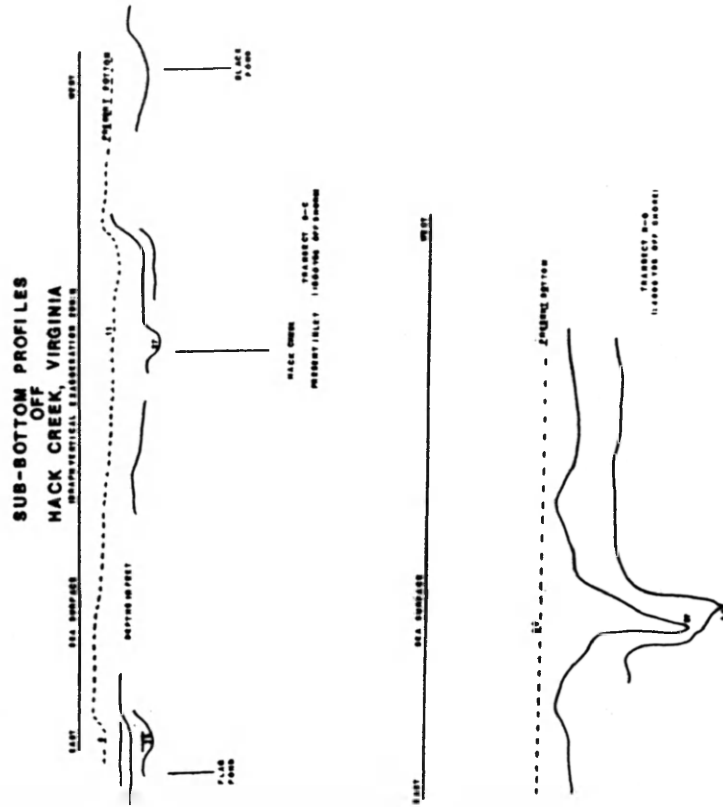


Figure 7. Sub-bottom seismic survey equipment.



SUB-BOTTOM SURVEY TRACK LINE RECORDED BY AN
X-Y LORAN PLOTTER ABOARD R/V CAPT. JOHN SMITH

Figure 8a. Sub-bottom seismic survey track lines collected in 1979.



b. Two select sub-bottom reflection record interpretations. Top (B-C) is closest to shore and bottom (N-0) is furthest offshore.

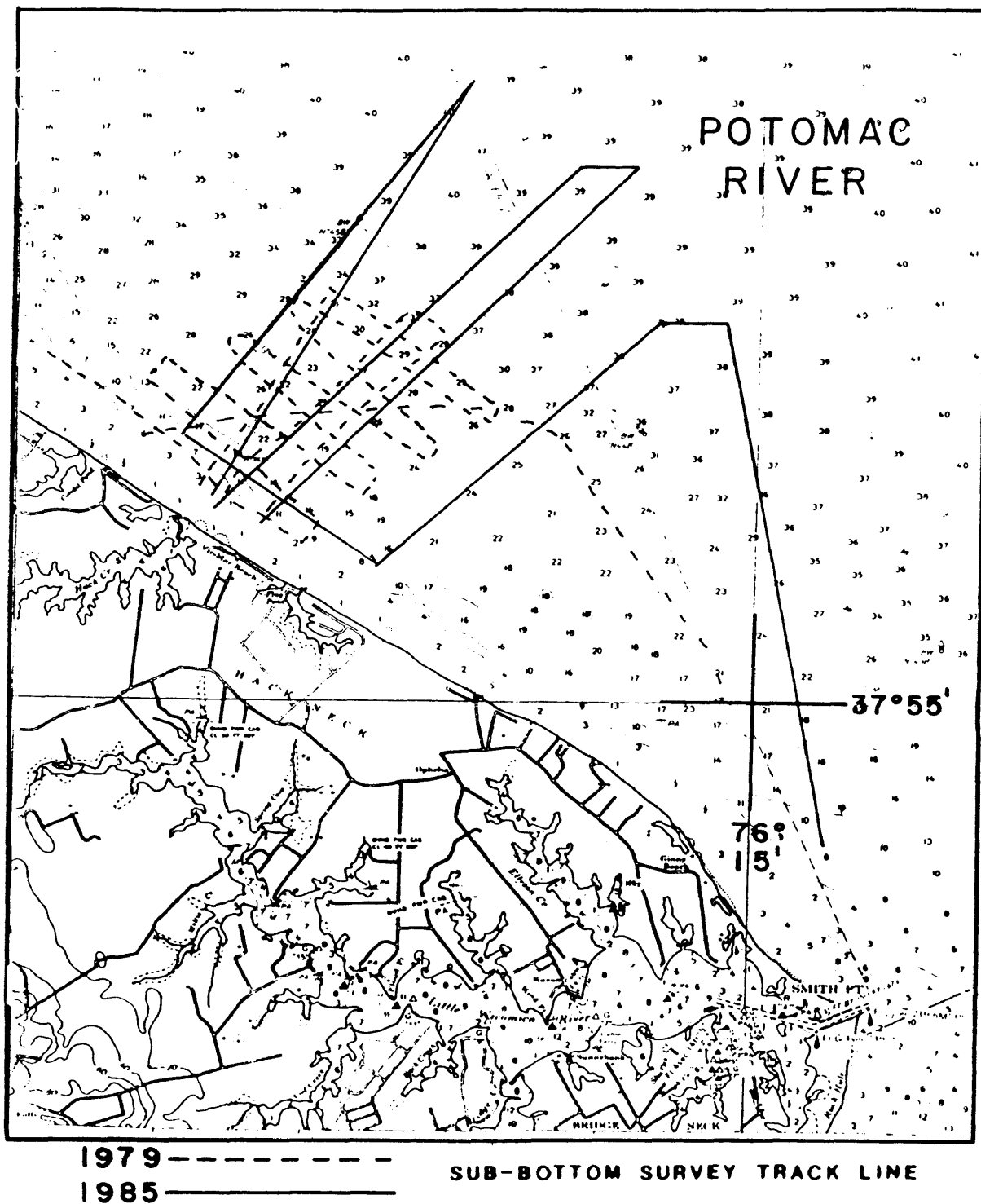


Figure 9. Sub-bottom survey track lines adjacent to Hack Creek, Virginia (from NOAA Chart 12233).

This survey employed a Datasonics SBP-5000 variable frequency system with a frequency range of 3.5 kHz to 7.0 kHz with up to 12 Kw output. The system allows high resolution of shallow seismic reflectors and displayed both the sub-bottom reflectors and the present bottom (200 kHz) on a two channel, EPC 3200, dry paper recorder. LORAN-C navigation was utilized to record both time differences (TD) and latitude and longitude positions, in order to accurately compare track lines from the two surveys. The Datasonics system proved beneficial in delineating stratigraphic units and morphological features that were in question from the first survey. Figures 10 and 11 compare the same section of track line utilizing the two surveying systems. The ability to change frequency on the Datasonics unit allowed data to be collected in areas previously obscured by surface sediments (i.e. thick layers of Holocene mud).

Vibracoring

An expandable vibracoring unit was employed to obtain continuous stratigraphic sections of up to 8 m (26 ft.) in length. The vibracoring unit uses a steel core-barrel with an 8.9 cm (3.5 in.) diameter clear plastic liner. The unit is free standing and uses a pneumatic, vibrating power head and gravity to drive the core barrel into the bottom (Figure 12). Rate and depth of penetration are recorded on a penetrometer. Once the equipment was hoisted back onto the platform and the sediment-filled liner removed, cores were labeled and cut into 1.5 m (5 ft.) lengths, capped and sealed. Seven cores were obtained, three

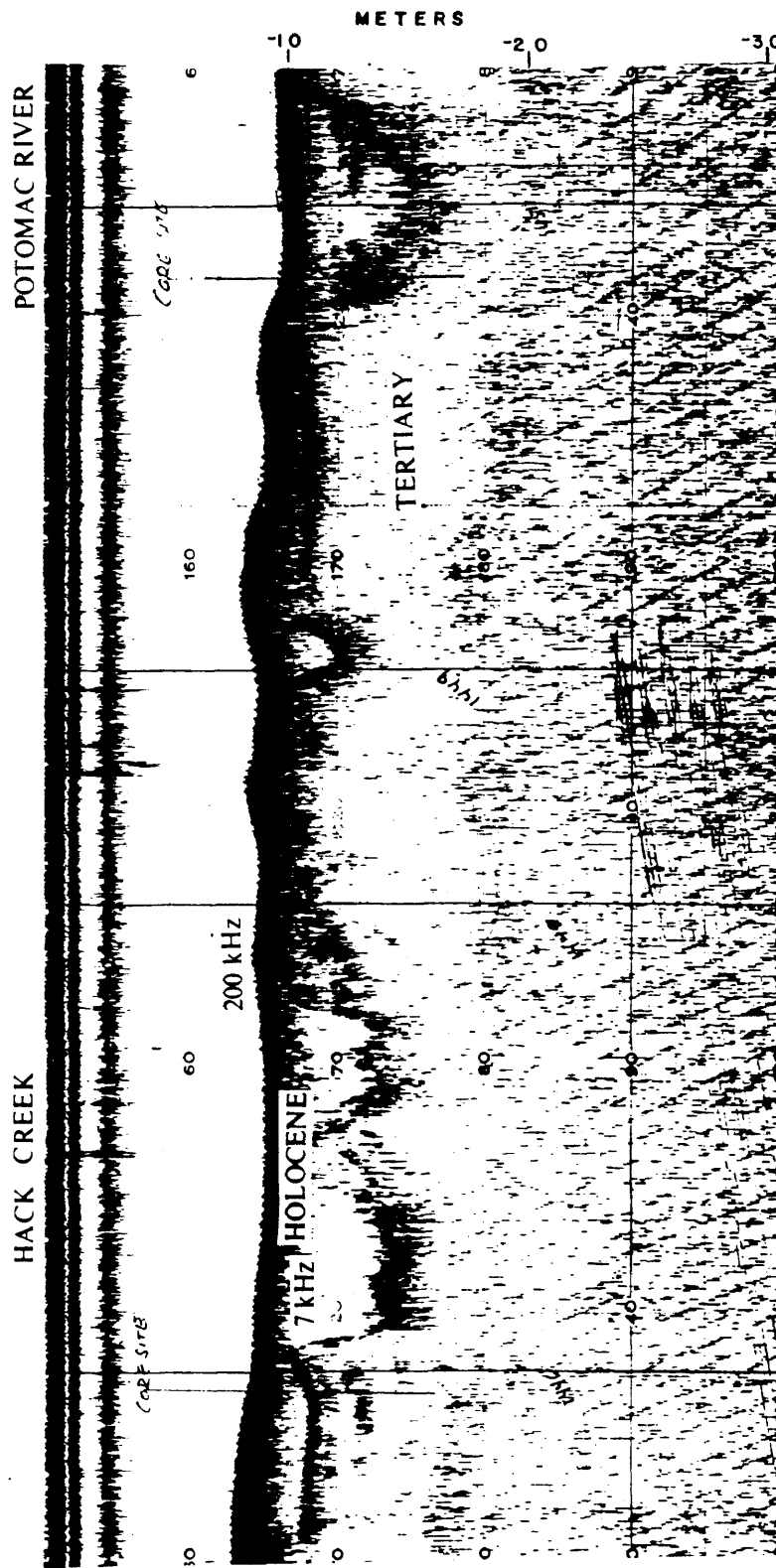


Figure 10. Seismic reflection record collected in 1979 using the RTT 1000. Surface layers and Tertiary bedding are not well defined.



Figure 11. Seismic reflection record collected in 1985 using the SBD-5000. Surface layers and Tertiary bedding are well defined.



Figure 12. Vibracore unit.

adjacent to Hack Creek, two at the mouth of the Potomac River and two south of Smith Point (Figure 13). The cores ranged in length from 3 to 8 m (9 to 26 ft). Although the cores at the mouth of the river and at Smith Point were not directly related to this study, the data were available to delineate seismic reflectors.

Other Methods

Sub-surface data were obtained from 10 hand-auger borings, 8 well logs from the Virginia Division of Mineral Resources, 20 marsh cores and thickness probes in the softer Holocene sediments of the creek systems. These data were supplemented with information from natural and manmade outcrops within the study area. United States Geological Survey 7.5 minute series topographic maps were used to locate and plot sampling locations. G.H. Johnson (personal communication) supplied data on the Pleistocene formations and geomorphic features in the study area.

In the laboratory the core sections were cut longitudinally, logged, photographed and sampled at contacts of major stratigraphic units. Samples were analyzed for sand:silt:clay ratio and/or gravel:sand:mud ratios to characterize the material. This was achieved through standard procedures as described by Folk (1974) and Carver (1971). Percent gravel was determined by dry sieving the sample using a number 10 U.S. standard mesh (-1.0 phi) sieve. Percent sand was obtained by wet sieving the remaining sample using a number 230 U.S. standard mesh (4.0 phi) sieve. Pipette analysis was used to obtain silt and clay percents in the sample.

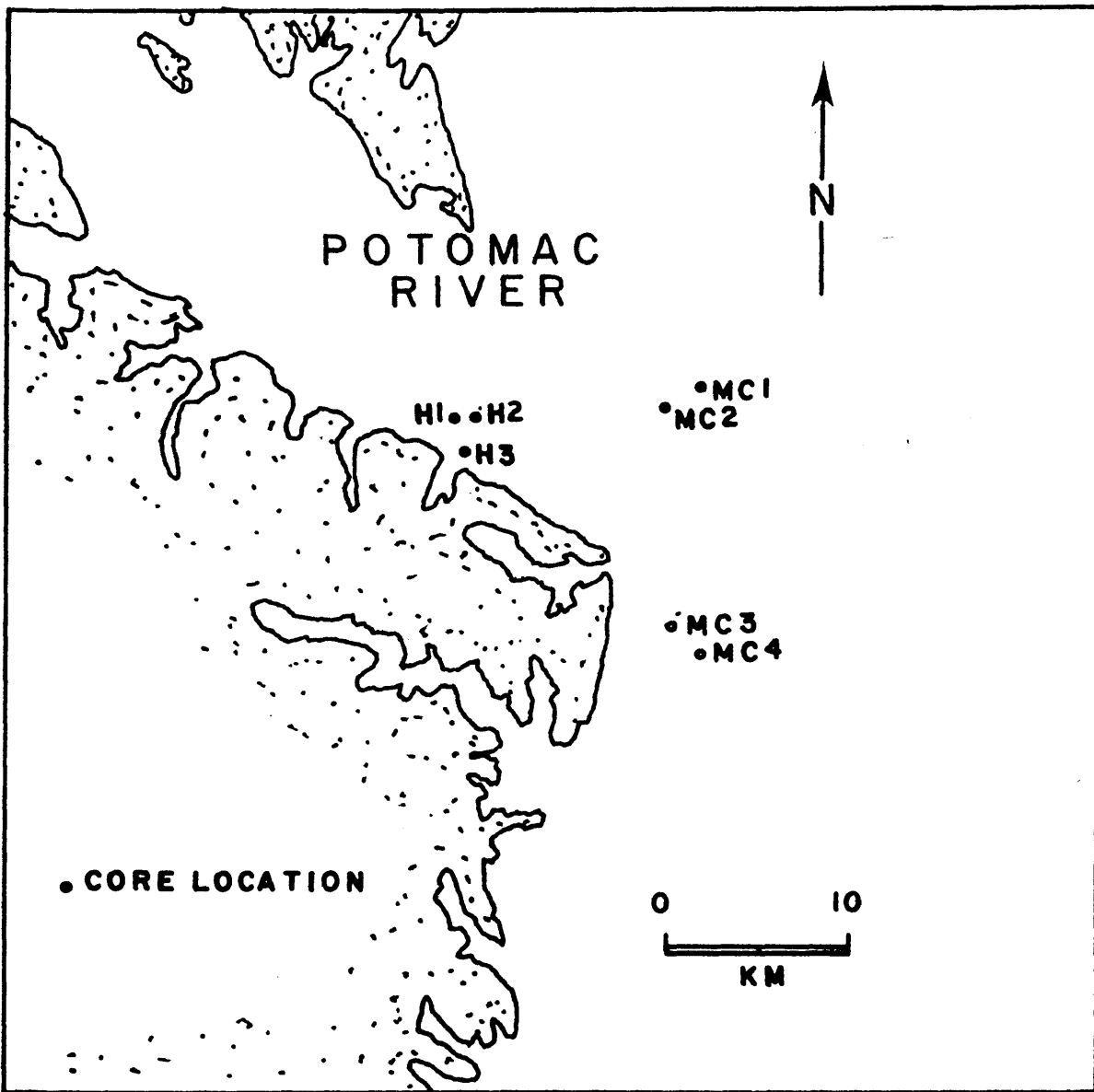


Figure 13. Vibracore locations near Hack Creek, Virginia.

GEOLOGIC SETTING

General Statement

Hack Creek is a natural estuarine system located on the Potomac River shore in Northumberland County, Virginia (Figure 1). This region is part of the Atlantic Coastal Plain, and is underlain by gravels, sands, silts, clays and marls of lower Cretaceous to Holocene age (Teifke, 1973). Most of the formations thicken to the southeast. Thus, the coastal plain sediments form a wedge-shaped body overlying crystalline rocks (Ryan, 1952).

The formations of Virginia Coastal Plain have been described and related by relative age (Johnson, 1969; Farrell, 1979; Peebles, 1984; Mitchell, 1984; among others). While most of the surficial formations of the Lower Coastal Plain are Quarternary in age, Tertiary sediments crop out at or near sea level over much of the area. Beginning in late Pliocene time, each successive high stand of sea level was relatively lower than the previous high stand; therefore, scarps, terraces, and sedimentary units become younger towards the present shoreline (Mitchell, 1984). The formations underlying the terraces are complex assemblages of sedimentary units deposited under marine, estuarine, and fluvial processes during the Pleistocene (Peebles, 1984).

The exposed strata in the Hack Creek study are: 1) the Chesapeake Group, a thick section (as much as 122 m) of lower Miocene to Pliocene

unconsolidated sediments that have diverse lithologies and low dip (Glaser, 1971); much of this section consists of interbedded sands, silts and clays; 2) The Westover Group (Johnson and Berquist, in press), previously referred to as the Columbia Group (Teifke, 1973) in part, a much thinner section (less than 50 m) of Pleistocene to Holocene unconsolidated sediments; the sediments are mainly oxidized clays, silts, sands, and gravels; locally and particularly near the present coastline, carbonaceous and peaty sediments are present (Teifke, 1973). The sediments of the Westover Group contrast sharply in consolidation, biota and mineralogy from the underlying marine formations.

Landforms

The Virginia Coastal Plain is characterized by scarps and terraces. The scarps represent erosional features, relict shorelines, while the terraces are the aggradational surfaces of stratigraphic units (Figure 14). The Suffolk scarp (Figure 15) separates the lowland deposits from the upland deposits along the Chesapeake-Potomac estuary (Glaser, 1971). On the Virginia side of the Potomac River the scarps and terraces were mapped by Johnson (personal communication). The scarp and terrace features are continuous throughout the study area and distinguishable on the Burgess 7.5 minute quadrangle. The landforms represented in the study area are the upland, two scarps (Suffolk and Big Bethel), and two terraces (Todd and Hampton Flats) (Figure 16).

The upland occurs at elevations between 14 and 31 m (45 and 100 ft). The latter forms the divide between the Potomac River and the

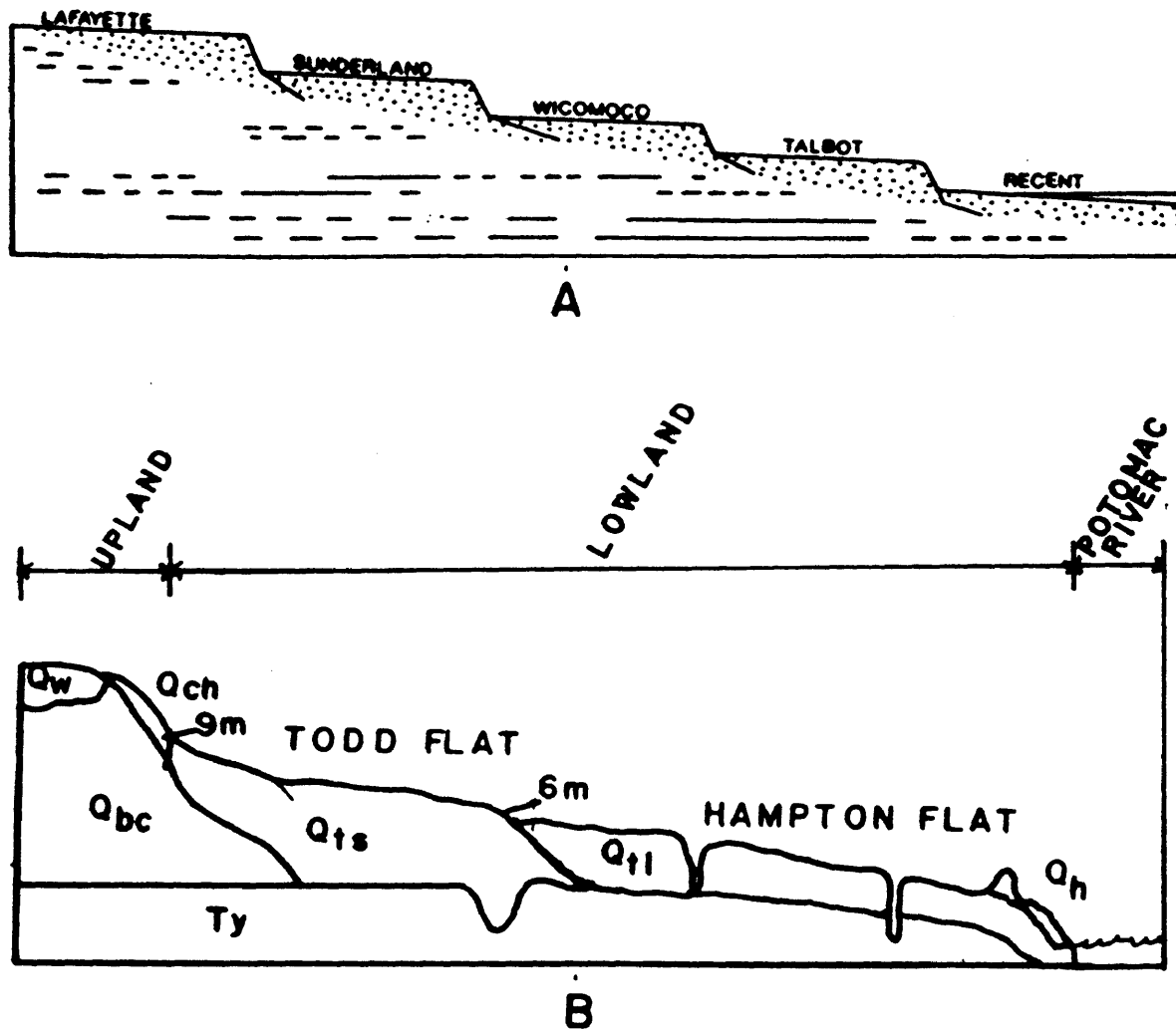


Figure 14. Diagrammatic cross section showing a) the terrace formation concept of Shattuck (1906) and b) the geomorphic and stratigraphic framework of the study area.

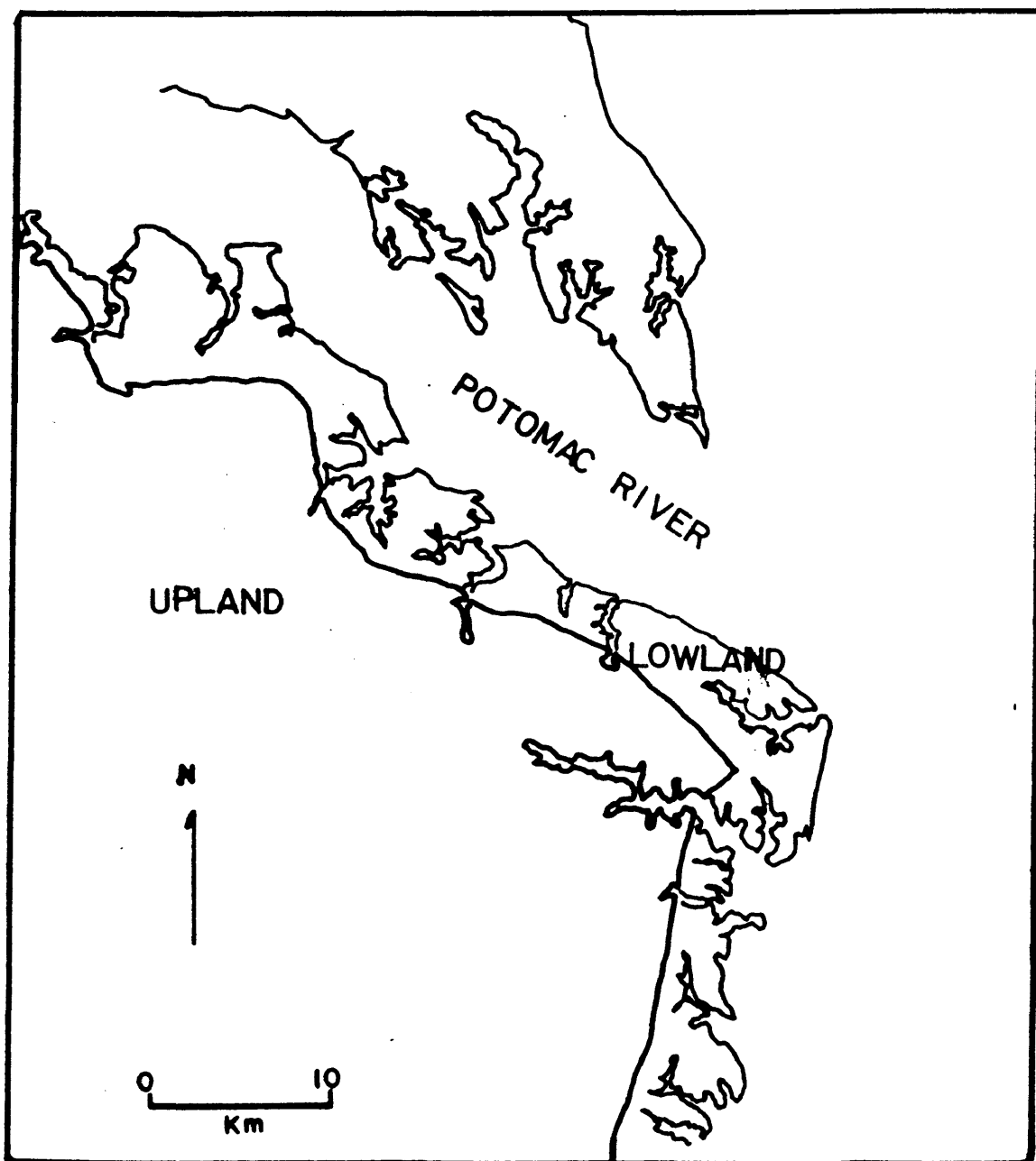
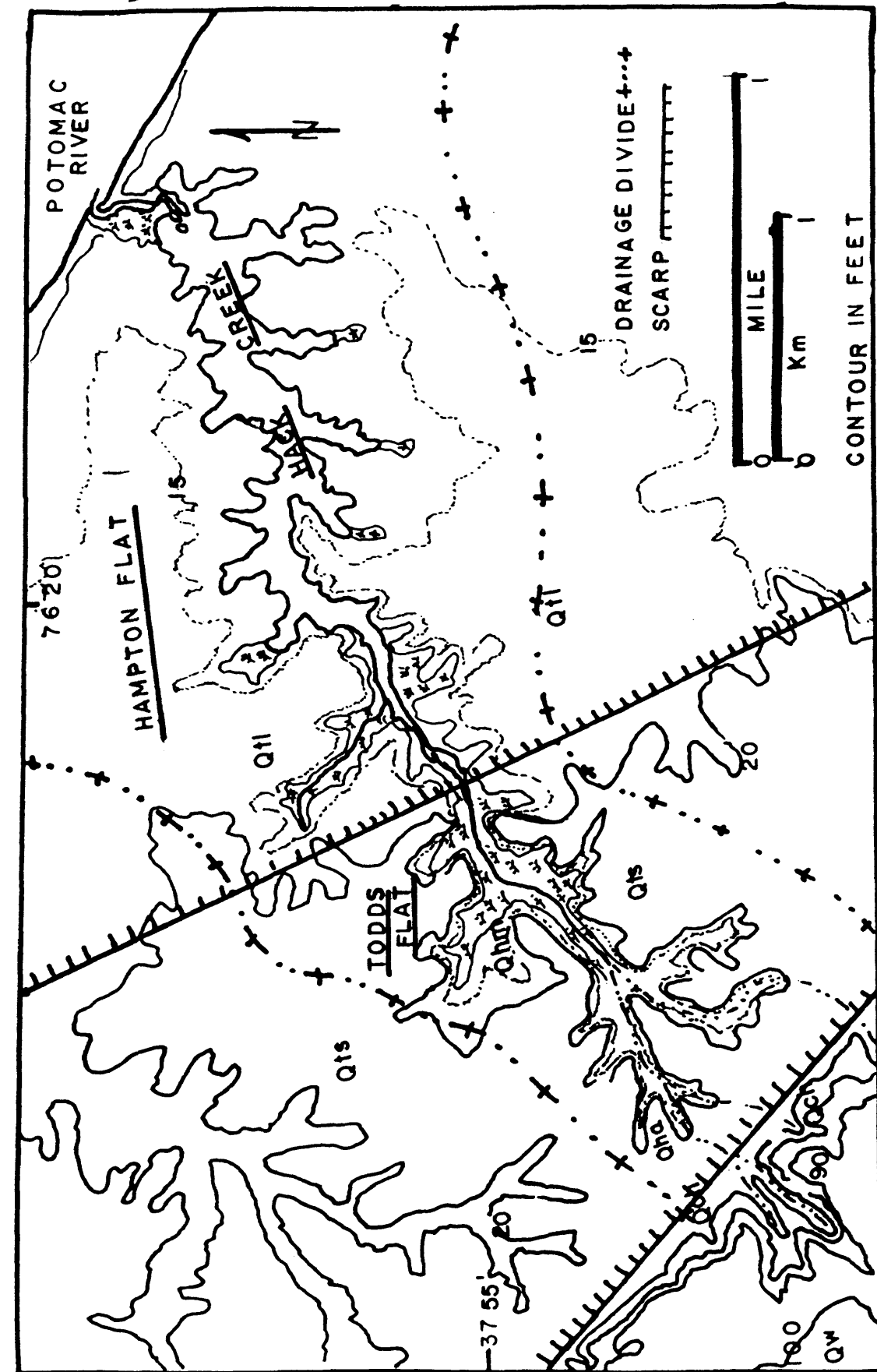


Figure 15. Relict shoreline of the study area showing upland and lowland areas.



Rappahannock River drainage basins. Lower on the Northern Neck peninsula it also divides the Great Wicomico River Basin from the Potomac Basin. The upland is comparable to the Grove plain on the York-James peninsula (Johnson, 1972) and is easily identified on topographic maps by its characteristic elevation and highly dissected nature.

Sediments assigned to the Windsor and Chuckatuck Formations comprise the surficial deposits of the upland. The Suffolk scarp of late Pleistocene age separates the upland from the Todds flat. The scarp below the upland trends to the northwest, paralleling the Potomac River, and displays a high degree of erosional dissection from drainage streams.

The Todds flat occurs at elevations between 6 and 9 m (20 and 30 ft) and decreases in elevation to the northeast. The Todds flat is dissected with fluvial drainage streams which have carved this flat locally to sea level. Sediments comprising the surficial deposits of the Todds flat consist of the Sedgefield Member of the Tabb Formation.

Big Bethel scarp has a toe elevation of 6 m (18 ft) and separates the Todds flat from the Hampton flat to the northeast. The Big Bethel scarp is not prominent, however it is perceptible at the 20-foot contour on the Burgess 7.5 minute quadrangle.

The Hampton flat (Johnson, 1972) ranges in elevation from 2 to 6 m (7 to 18 ft) and slopes very gently towards the Potomac River. The Hampton flat is highly dissected by tidal creek systems which are commonly cut to sea level. The Hampton flat terminates at the present Potomac River shoreline and is underlain by the Lynnhaven Member of the Tabb Formation.

STRATIGRAPHY

General Statement

Stratigraphic units ranging in age from Pliocene to Holocene are addressed in this study. The Pliocene age Yorktown Formation is not exposed in the study area; however it is recognized 6.6 m (22 ft) below sea level in well logs of the Virginia Division of Mineral Resources (Teifke, 1973) (Figure 17). The Yorktown Formation is not differentiated from the rest of the Chesapeake Group in the seismic reflection records. The Tertiary sediments of the Chesapeake Group have an acoustic signature or characteristic return that can be correlated between profiles. The Pleistocene formation of this study disconformably overlies the Tertiary age formations. The Windsor and Chuckatuck Formations, and two members of the Tabb Formation, the Sedgefield and Lynnhaven, were mapped in the study area by Johnson and Peebles (in press) and Berquist (personal communication). Holocene deposits occur in the streams, tidal creeks, along the shoreline, and offshore in the Potomac River Estuary. Holocene deposits include alluvium, marsh, beach and dune sediments (Figure 17).

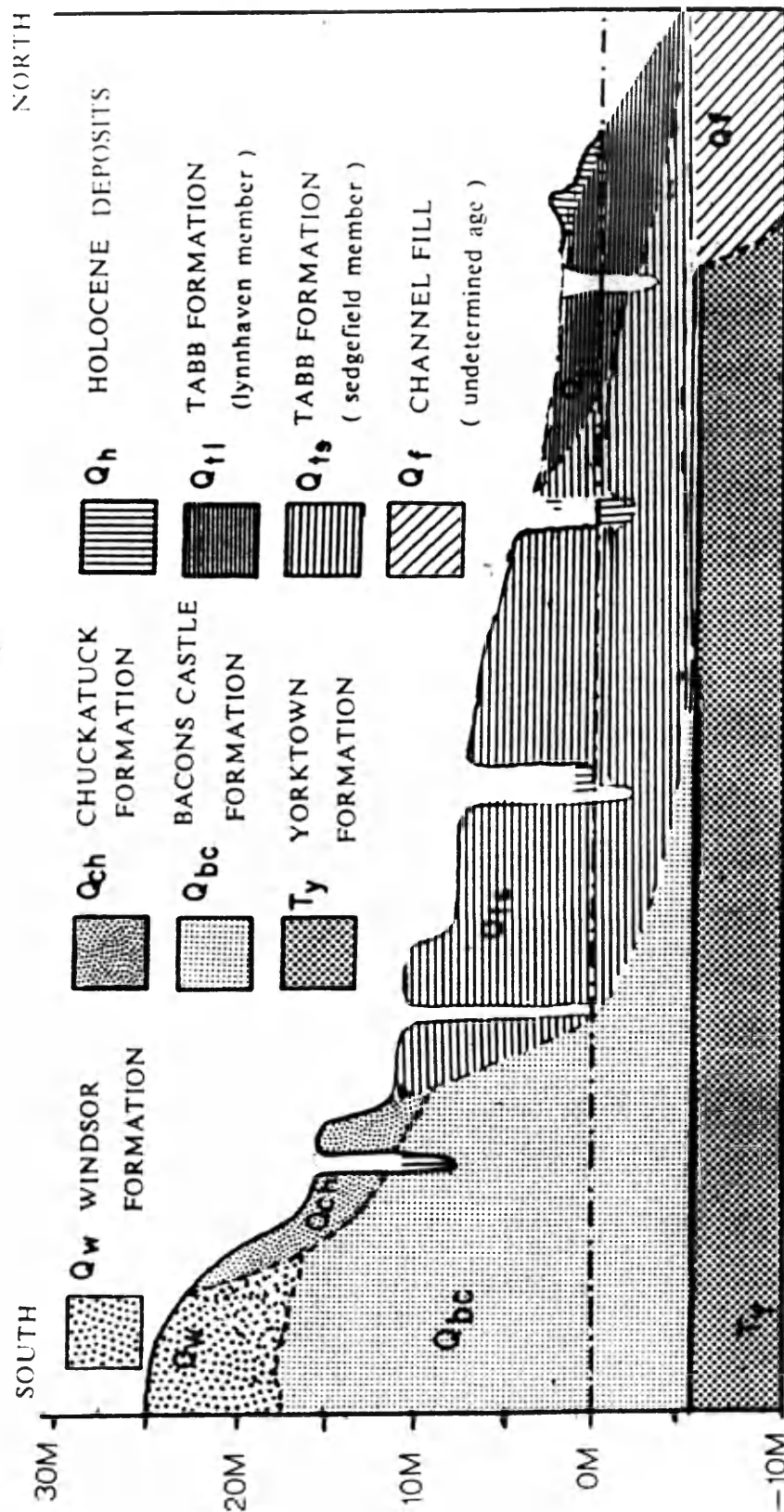


Figure 17. Schematic diagram of stratigraphic units in the study area.

Pliocene Series

Yorktown and Bacons Castle Formations

The Yorktown Formation is a wedge of marine sediments that thickens to the east and south and is underlain by older Tertiary and Mesozoic units. The Yorktown Formation is assigned an early Pliocene age (Ward and Blackwelder, 1980). The top surface of the formation is an erosional disconformity. Within the study area the Yorktown Formation (Teifke, 1973) consists of clean, light gray, medium to coarse grained sand with traces of weathered glauconite, carbonaceous material and shell (Figure 18). Near the Hack Creek study area the surface of the Yorktown Formation is reported at -6.6 m (-22 ft) with a thickness of 10 m (33 ft). The thickness of the Yorktown Formation underlying the shoreline suggests that the deep paleochannels of the Potomac River (Knebel et al., 1981) have totally incised this formation. Seismic reflection records indicate the Yorktown Formation has horizontal or gently dipping beds, this makes the formation easy to identify from the cross bedding associated with channel fill material. The Bacons Castle Formation overlies the Yorktown Formation disconformably and is comprised of a basal silty pebbly sand fining upwards into very silty and clayey sands nearshore marine and intertidal.

Pleistocene Series

Windsor and Chuckatuck Formations

The Windsor Formation crops out in the upland of the study area and is distinguishable only in the uppermost elevations of the uplands

(Figure 18). The Windsor Formation consists of fine to medium sand fining upwards to silty sand and clay. The sediments of the Windsor Formation are much more weathered than the younger deposits. The Chuckatuck Formation also crops out in the upland and along the Suffolk scarp. The thickness of the Chuckatuck Formation in the study area is unknown, but the formation consists of a basal silty, pebbly sand which fines upward to a clayey sand. The gravel fraction of this unit is granule to pea size.

Tabb Formation

The Tabb Formation was named by Johnson (1976) and originally mapped on the James-York peninsula. There are three members of the Tabb Formation, the Sedgefield, Lynnhaven, and Poquoson. Only two members of the Tabb Formation are recognizable in the study area, the Sedgefield and the Lynnhaven (Johnson, personal communication).

Deposits of the Sedgefield Member of the Tabb Formation underlie the Todds flat within the study area. The Sedgefield Member is a fining upward sequence with a thin gravelly surface layer. A basal reddish brown, weathered gravelly sand, grades upwards into a gray pebbly sand, and is overlain with a distinct contact of clean, fine white sand. Cross-bedding exposed in local sand and gravel pits with some beds dipping in excess of 15° provides strong evidence that the Sedgefield Member had a fluvial state near the end of its depositional phase.

The Lynnhaven Member of the Tabb Formation underlies the Hampton flat and ranges in elevation from 2 to 6 m (7 to 10 ft) within the study area. The Lynnhaven Member consists of a fining upward sequence of

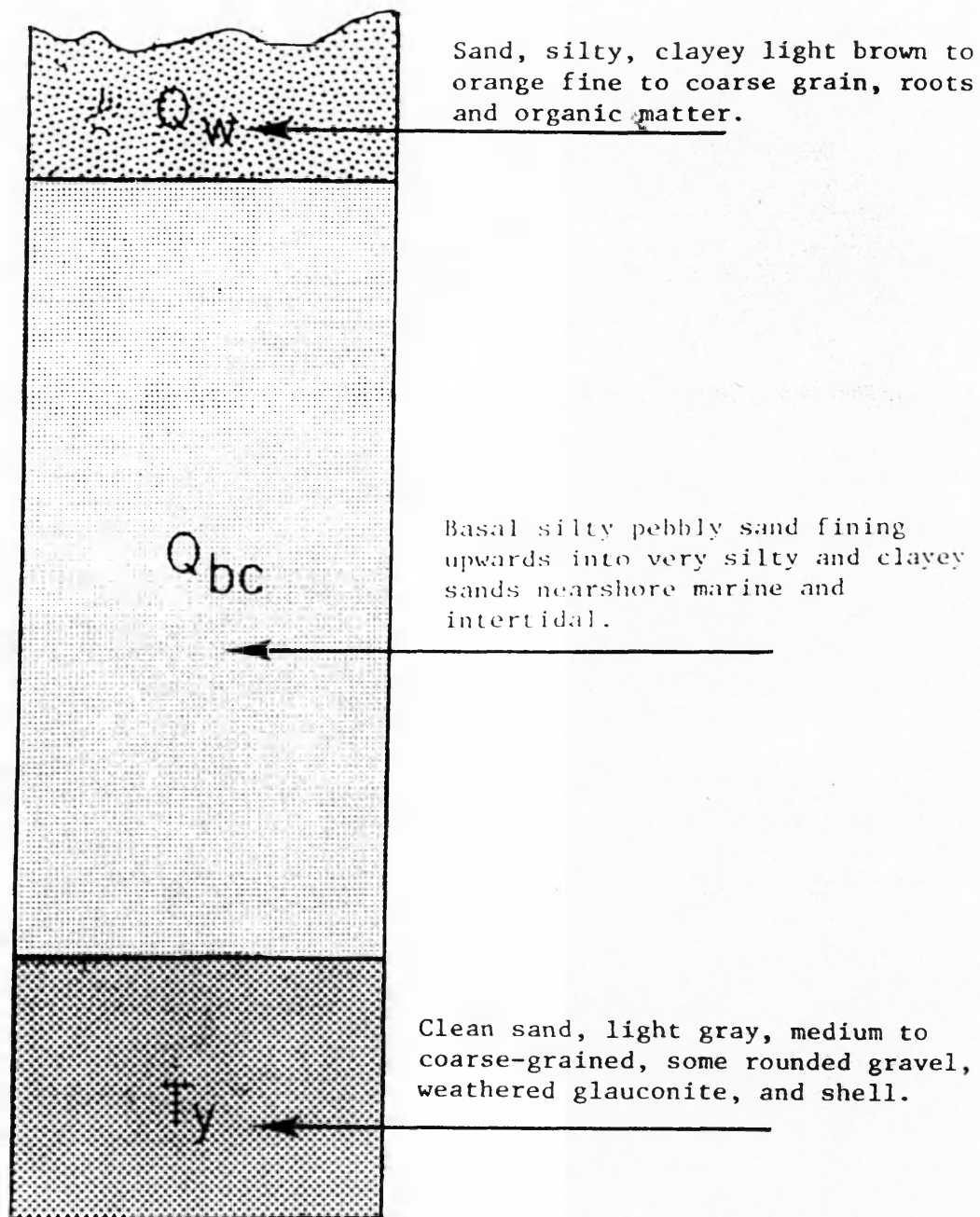


Figure 18. Stratigraphic section of uplands in the study area.

gravelly sand that grades upwards into a fine sand with silty clay near the surface. Since the surficial sediments of the Lynnhaven Member are a fine sand with silt and clay, water often stands on the surface and makes the unit easy to identify without the aid of topographic expression. The thickness of the Lynnhaven Member is not known; however seismic profiles indicate that the lag deposit associated with the base of this unit rests unconformably on the Yorktown Formation (Figure 19). The Yorktown Formation is -6.6 m (-22 ft) below sea level; therefore the maximum thickness of the Lynnhaven Member would be 12 m (40 ft).

Holocene Series

Holocene sediments overlie older deposits along low-lying areas bordering the Potomac River in the stream valleys of the study area and offshore in the Potomac River (Figure 19). These deposits consist of tidally-influenced and freshwater marsh, estuarine muds, alluvium, and beach and dune sands. Marsh deposits are brown-black, organic-rich silts and clays. Within the tidal delta the basal marsh layer is coarse sand. The maximum thickness of marsh deposits in the study area is about 6 m (20 ft).

Estuarine muds exist in the Potomac River channel and the tidal creeks. Estuarine deposits consist of watery, gray to black clay or silty clay, with fine sand. The maximum thickness of the estuarine muds in the Potomac River reported by Knebel et al. (1981) was 14 m (46 ft). Beach and dune sands occur along the Potomac River shoreline and in the inlet mouth at Hack Creek. The maximum dune height is 3 m (10 ft).

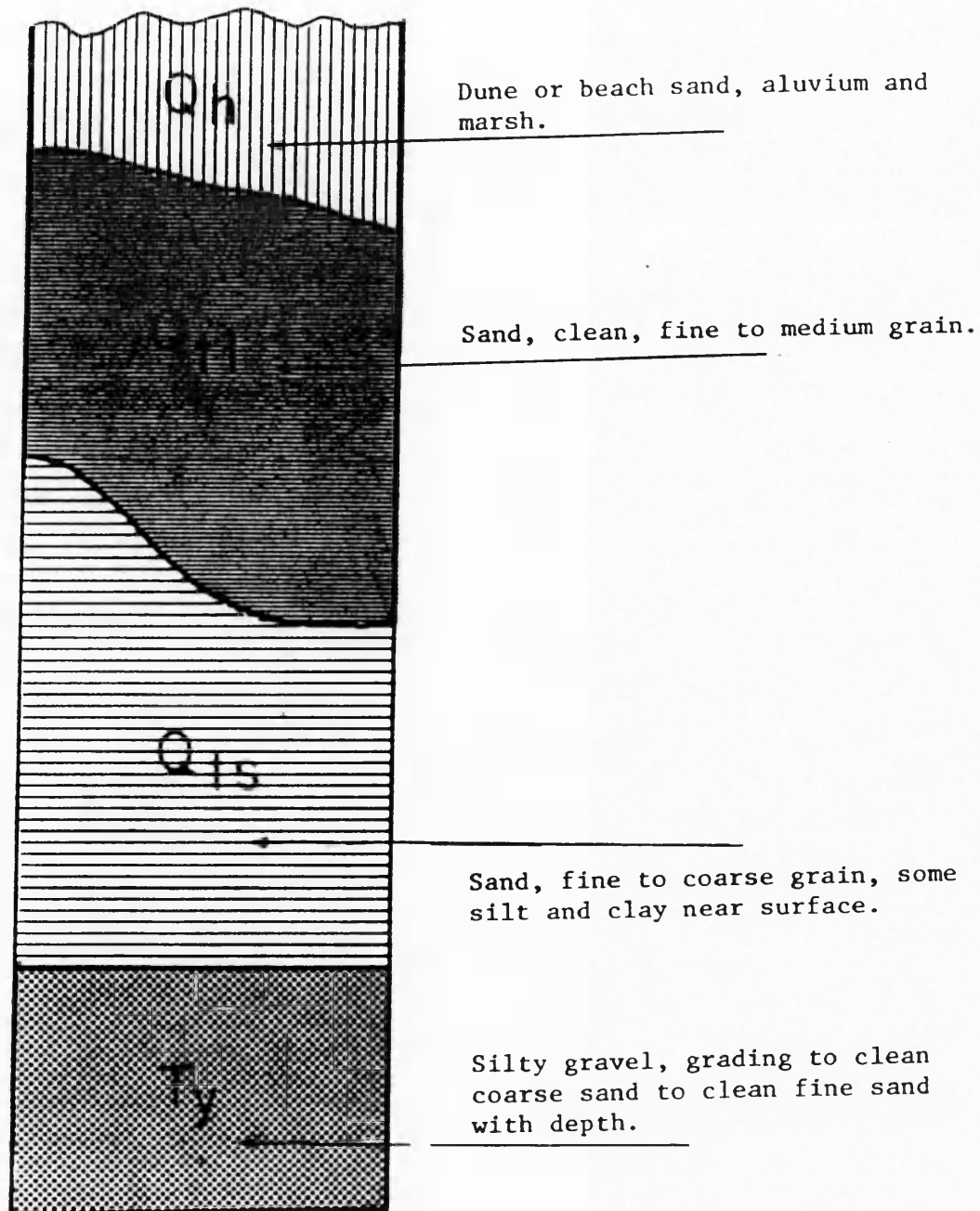


Figure 19. Stratigraphic section of lowlands in the study area.

Alluvial deposits are found in channel bottoms and interbedded with marsh deposits throughout the study area. The maximum thickness of Holocene alluvial deposits found in the study area is approximately 0.5 m (1.6 ft).

Physical Setting

Hack Creek is typical, in respect to its cross sectional area and tidal prism, of most of the inlet-basin type drainage systems (Byrne et al., 1980). It is a sub-estuary of the Potomac River and exhibits the lateral and vertical facies succession formed during a marine transgression.

The inlet at Hack Creek has been stabilized to prevent migration along the beach. A long sinuous inlet channel terminates in a flood tidal delta. Coarse to medium grain sand is actively being deposited on this delta. The tide range in the Potomac River at Hack Creek is approximately 0.9 m (3.0 ft). The impedance of the inlet channel reduces Hack Creek's tidal range to approximately 0.36 m (1.0 ft). A salt marsh (*Spartina alterniflora*) is established in the abandoned inlet channel and the older lobes of the delta (Figure 20).

Estuarine deposits of fine sand, silts, and clays are deposited in the axis of the system to a thickness of approximately 6 m (20 ft). The bathymetry of Hack Creek exhibits no active channels in the main stem of the system (Figure 21); however, a paleothalweg was observed by probing and seismic surveys (Figures 21 and 22). The branches of the system all terminate in pocket marshes incised by ephemeral streams controlled by

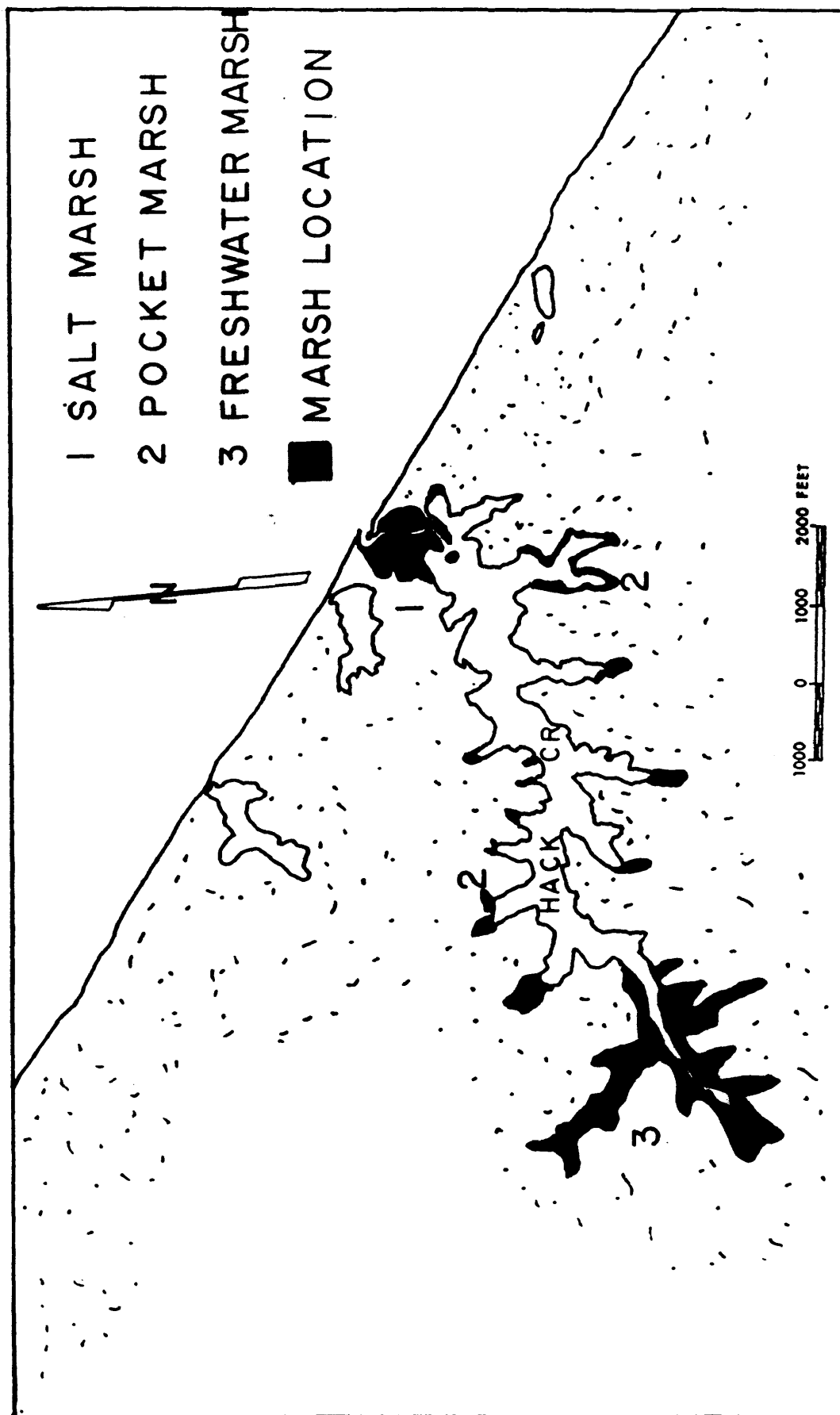


Figure 20. Marsh type and location at Hack Creek, Virginia (after Silberhorn, 1975).

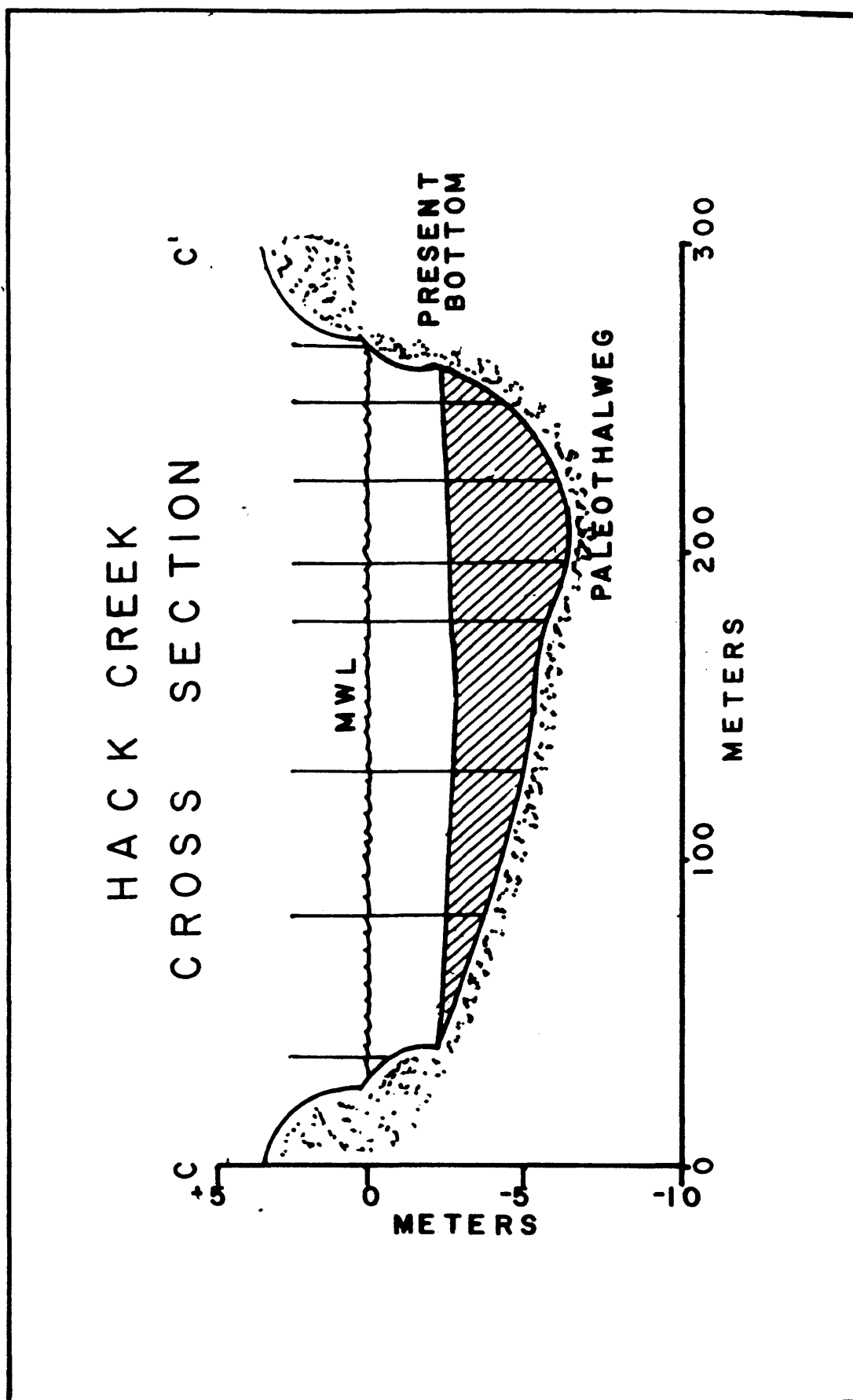


Figure 21. Cross section C-C' in Hack Creek showing bathymetry of the present bottom and probe sites.

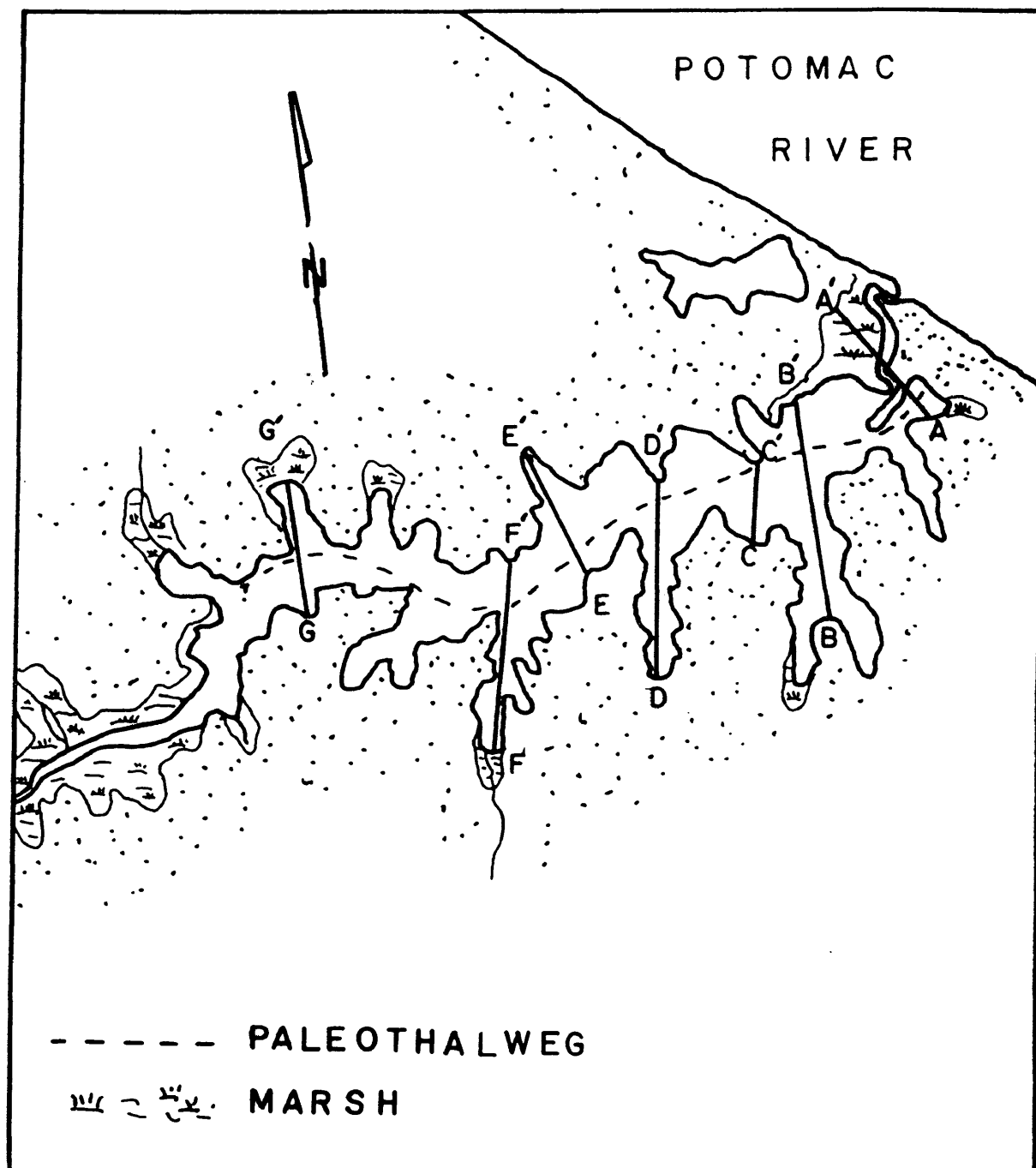


Figure 22. Transects and paleothalweg position in Hack Creek, Virginia.

local runoff. These marshes appear to be traps for organic detritus derived from upland sources (i.e. leaves, wood, etc.). The upper one-third of the basin is intermittently brackish water during storm or spring tide events. The result is a marsh comprised of saltgrass meadow hay (Distichlis spicata L.), Olney threesquare (Scirpus oireyi), and cattail (Typha angustifolia L.) flanks the shoreline (Figure 20). Deposits of organic material approximately 3 m (10 ft) thick are present in the area.

At the head of the basin a large beaver dam controls the fluvial discharge into the system (Figure 23). The freshwater influx was calculated to be 0.37 m^3 per second using flow meters in a restricted region of Hack Creek, above tidal influence. Measurements before and after wet periods displayed little variance with rainfall. The uniformity of flow is thought to be caused by the impeding effect of the beaver dam acting as a weir or spillway. Above this restriction is an extensive swamp (paludal environment). The edaphic succession of deciduous trees in the swamp area is red (swamp) maple (Acer rubrum), sweet gum (Liquidambar styraciflua), black gum (Nyssa syriatica), willow oak (Quercus phellos), and white oak (Quercus alba).

The fluvial channels of Hack Creek incise the topography of the uplands, and provide source material for fluvial deposits in the upper reaches. These fluvial deposits upstream can be delineated in the vertical succession of facies within Hack Creek (Figure 24). This system fits well in the model for Holocene stream valleys proposed by

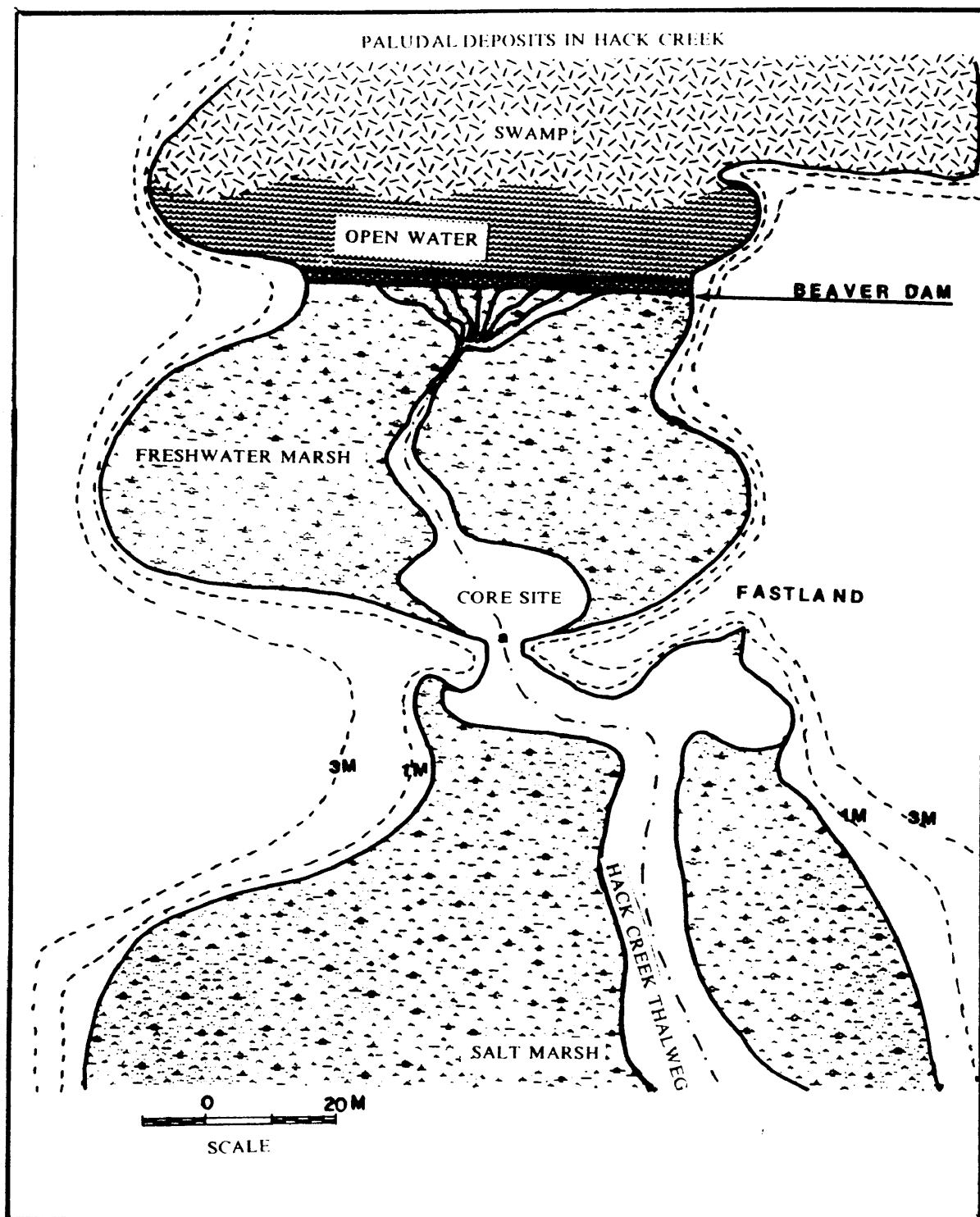


Figure 23. Schematic diagram of paludal environments at Hack Creek, Virginia.

HACK CREEK UPPER REACH

CORE

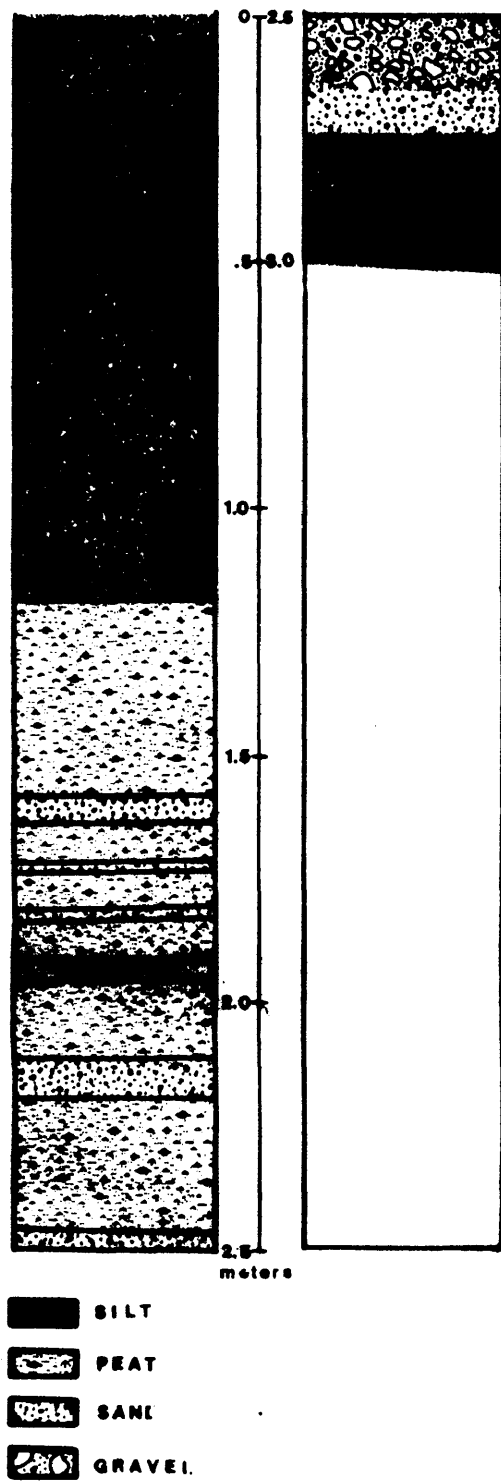


Figure 24. Core of sediment facies in Hack Creek, Virginia.

Peebles (1984). Steep valley walls and narrow valley floors are observed in the Hack Creek paleochannels.

Bathymetry along the shoreline of the Potomac River, adjacent to Hack Creek, exhibits evenly spaced contours to the 10 m depth (30 ft.) where the Potomac River Channel begins and the sediments change from sand to silty sand to mud. Knebel et al. (1981) divided the Potomac River Estuary into three lateral morphological units - shoreline flats, transitional slope and channel bottom. The widths of these units in the study area are: shoreline flats-100 m; transitional slope-3 km; and channel bottom-7 km (Figure 25).

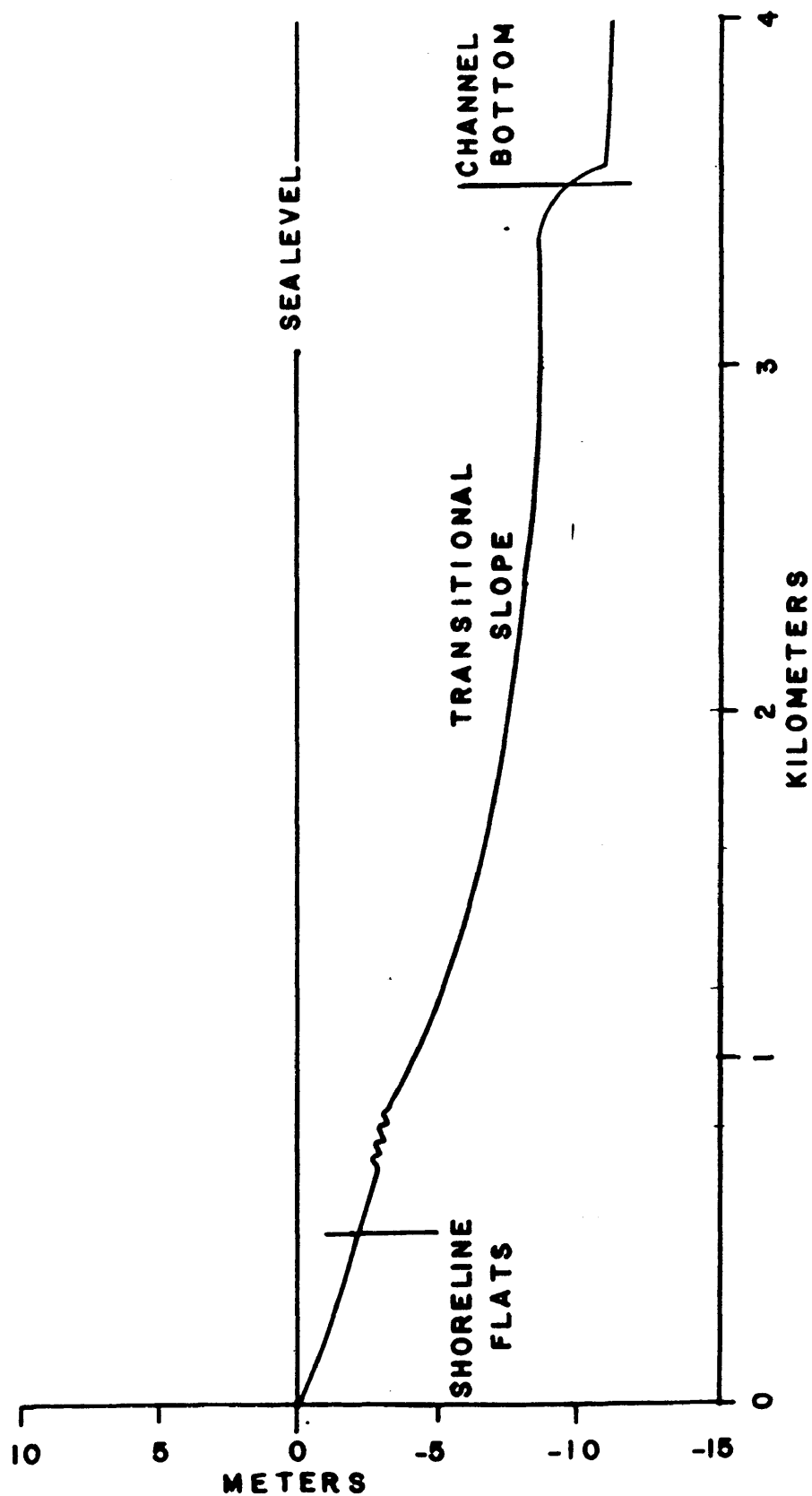


Figure 25. Potomac River bottom units at Hack Creek, Virginia (after Knebel, 1981).

RESULTS AND DISCUSSION

When charts of the Chesapeake-Potomac estuary are examined, it is evident that very little, if any, expression of relict channels from the hundreds of sub-estuaries, ponds, and tidal creeks are observed in the bathymetry of the nearshore flats. The larger systems- Little Wicomico, St. Mary and other rivers- show some inshore bending of the bathymetric contours adjacent to their present inlets or mouths; but no relict thalwegs are observable. If these systems were once part of the fluvial drainage of the area, the topography of these stream valleys are buried.

Remnants of this type of fluvial drainage can be observed in sub-bottom records throughout the Chesapeake Bay and its tributaries (Carron, 1979; Knebel et al., 1981; Colman et al., in prep). Minor paleochannels have been inferred for existing sub estuary ponds and tidal creeks, however, no prior research exists in the literature that confirms a contiguous set of paleochannels connecting the present upland drainage with the paleodrainage of a major river. This data could provide evidence to whether these systems represent more than one transgressive-regressive cycle. A sub-bottom seismic reflection survey adjacent to Hack Creek completed in this study in the spring of 1979 (Figure 8a) delineates a complex paleochannel system. Sub-bottom seismic profiles indicate that three major horizons or acoustic

reflectors exist in the nearshore of the Potomac River adjacent to Hack Creek (Figure 26).

The acoustic basement in the study area is made up of sediments from the Chesapeake Group (Hack, 1957). Knebel et al. (1981) reported this to be a thick section (as much as 122 m) of unconsolidated sediments of Tertiary age. The lack of a basal reflection horizon and the erosional disconformity at the surface of this Tertiary formation permit it to be used as a basement for all younger stratigraphic units addressed in this study (Figure 27).

The surface reflector (Figure 26, Unit A) is reworked sand derived from shoreline erosion and longshore transport. Near the beach this material is a medium to coarse grained sand with fossil shells that form a series of linear bars parallel to shore. These bars terminate at the -3 m (-10 ft.) contour. A line of sediment samples, normal to the shore, shows that the sand fines with increasing depth and grades to a muddy sand at the edge of the Potomac River Channel. For this study, the edge of the channel is defined as the -9 m (-30 ft.) contour. Sediment samples from cores indicate the channel is being filled with fine grained Holocene sands, silts and clays. The second unit (Figure 26, Unit B) appears to represent a continuous stratigraphic layer extending from the beach or fastlands to the Potomac River paleochannel; its surface is undulatory and highly dissected. This stratigraphic unit is incised with a complex system of paleochannels backfilled with a material which is acoustically different from the underlying unit. The third major unit (Figure 26, Unit C) is associated with the

SUB BOTTOM SEISMIC PROFILES (HACK CREEK, VIRGINIA)

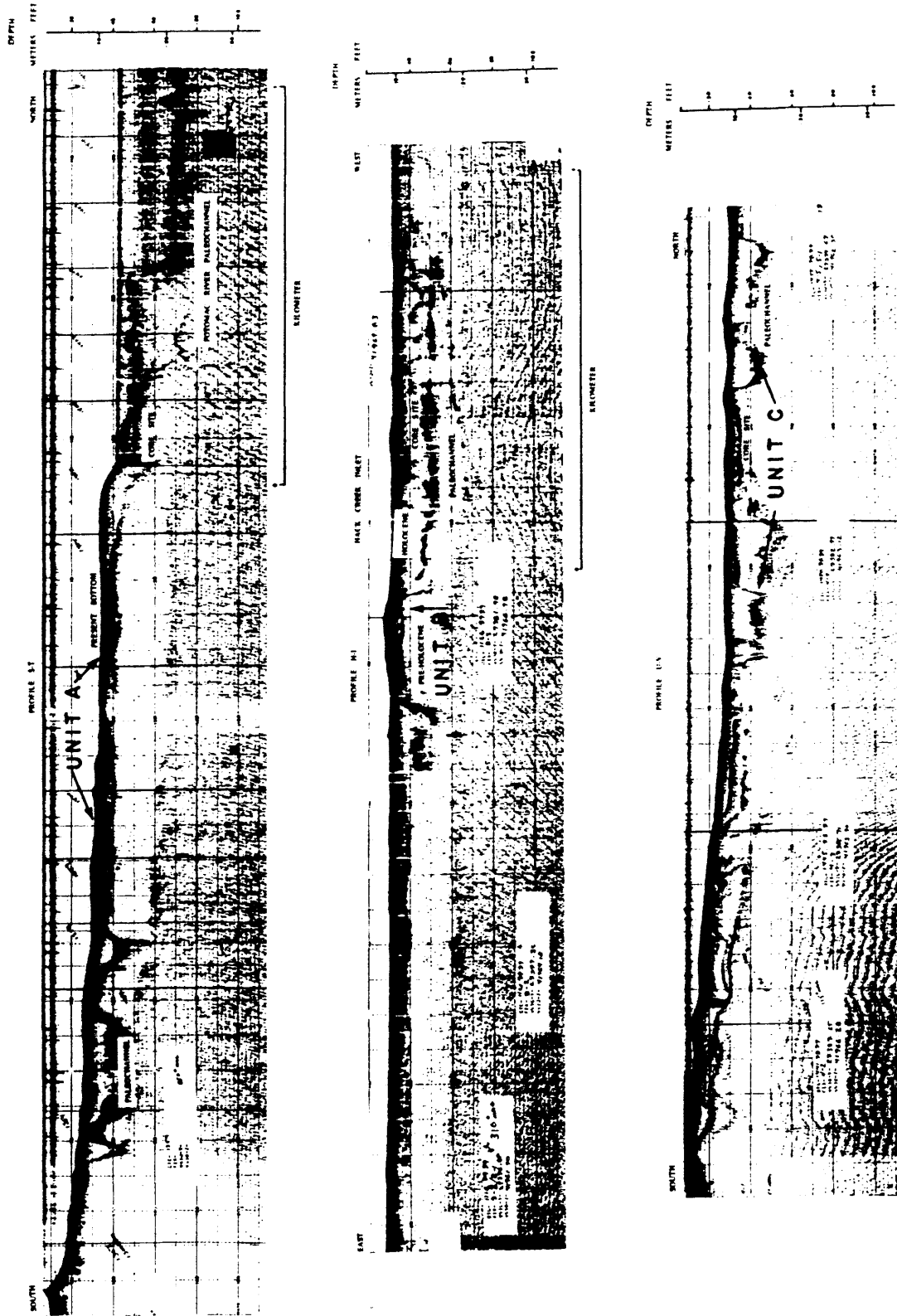


Figure 26. Three select sub-bottom seismic profiles displaying the three major acoustic reflectors, Unit A (surface reflector), Unit B (pre-Holocene) and Unit C (channel fill).

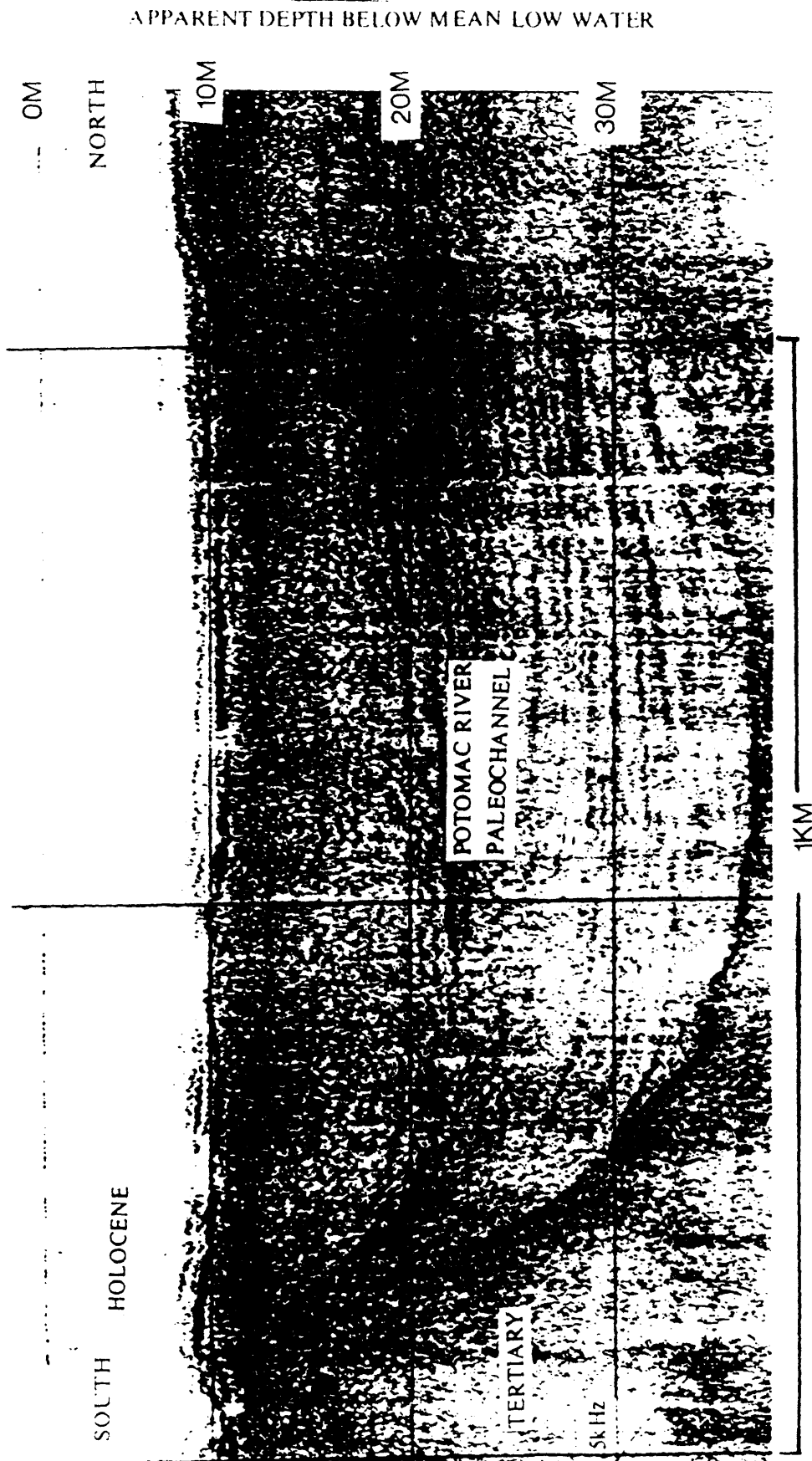


Figure 27. Sub-bottom reflection record of channel fill material in paleochannel B.

paleochannels. Vibracore samples prove this unit to be composed of deposits related to the fluvial channel phase and estuarine fill material of Holocene age. Figure 26 shows profiles displaying the three major reflectors. Profile S-T is normal to the shore and depicts a typical profile from the outermost sand bar to the Potomac River paleochannel. Profile H-I is parallel to shore 3.5 km (2.1 mi.) offshore.

The major Hack Creek paleochannel is directly riverward of the present Hack Creek inlet system. Plotting of all profiles in the survey delineated three major paleochannels near the shoreline. These merge into one deeply incised channel with an axis depth of -30 m (100 ft.). This one, deep channel is the only connection of the complex dendritic paleodrainage system with the Potomac River paleodrainage (Figure 8b). The thalweg depth and axis of the main paleochannels were compared with the axis of the paleothalwegs inside the Hack Creek system (Figure 28). A probe rod was used to develop a cross section of the marsh sediment and thalweg depth inside the inlet of Hack Creek. The thalweg in the basin is located approximately 8 m (25 ft) below mean low water and is not associated with the present inlet channel. Sub-bottom profile track B-C (Figure 8b), located 500 m (1650 ft) offshore, indicated a paleobasin with a channel thalweg at approximately -9 m (-30.0 ft) adjacent to the Hack Creek inlet. The axis depths of the channels and the proximity of the present system make it evident that the paleochannels were once a part of the Hack Creek system.

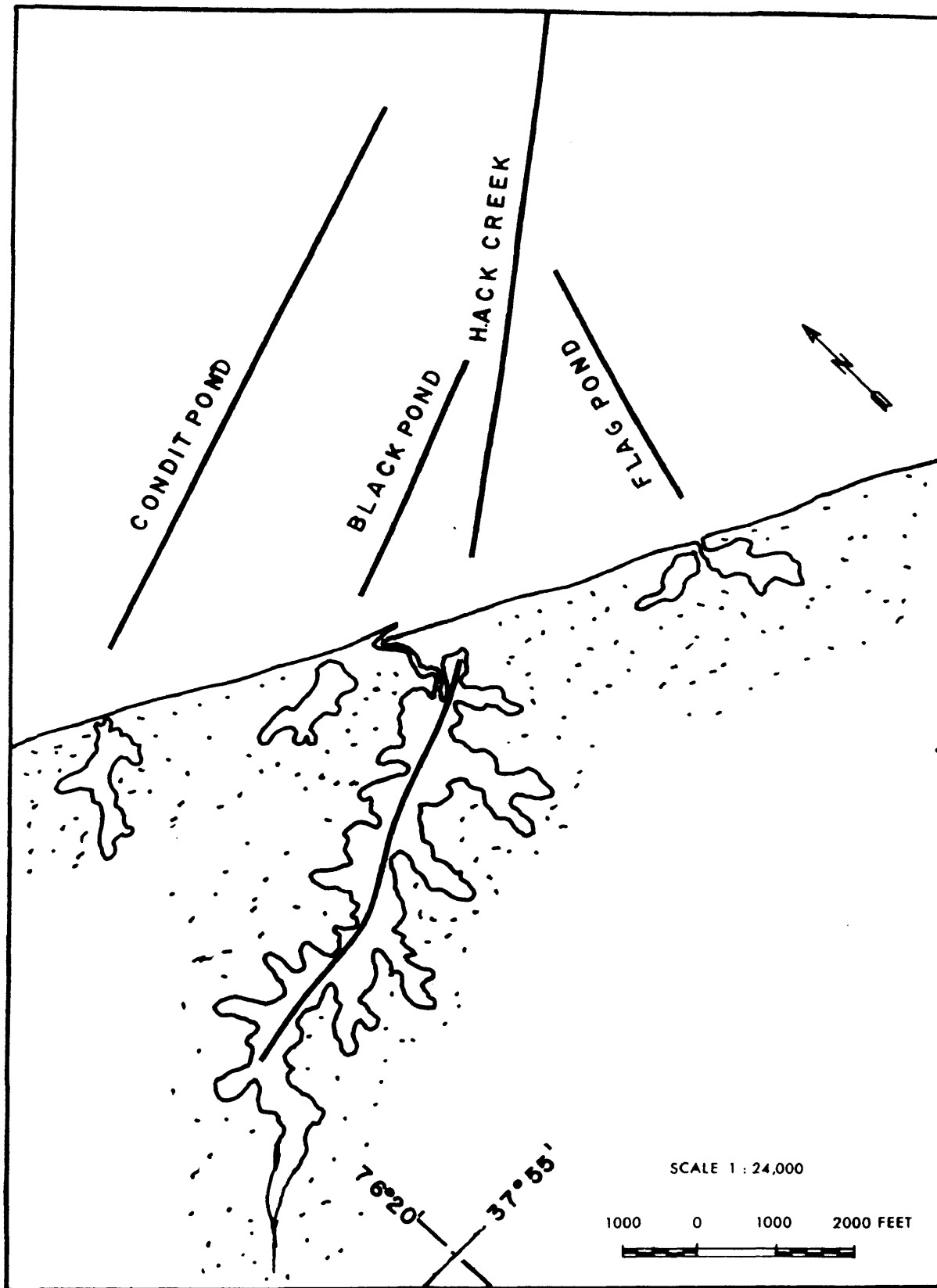


Figure 28. Trends of thalweg axes of Hack Creek and its tributary paleochannels (Burgess 7.5 minute quadrangle).

An analysis of the gradients of the present drainage, from the upland scarp + 15 m (50.0 ft.) above sea level to the inlet mouth, and of the paleochannel system, from the nearshore flats to the Potomac River paleochannel, indicates the depths of the thalwegs increase with distance offshore. The slope is always negative which would be expected if a channel were to support a fluvial drainage system (Figure 29). An increase in the thalweg slope, where the system merges with the Potomac River paleochannel, 4 km (2.2 nm) offshore, indicates that the system was perched from salt water or tidal intrusion until the late Holocene. This would suggest that stream competency was insufficient to allow the drainage system to evolve from a V-shaped, narrow and linear stream to a major Holocene stream having wide valleys with flat floors and meander channels (Peebles, 1984). This condition would allow most of the Hack Creek system to remain fluvial, long after the Potomac River had become estuarine and would explain the lack of fluvial fill material in the Hack Creek paleochannels.

The three other drainage systems near Hack Creek, Black Pond and Condit Pond to the west and Flag Pond to the east, have adjacent paleochannels offshore (Figure 8b). Core samples from the interior of these systems indicate that they have the same stratigraphic facies succession and morphology found in Hack Creek, with the exception of Black Pond. The upper sedimentary sequence of Black Pond represents a freshwater pond environment since anthropomorphic influence has disrupted natural evolution over the past 50 years. The three dimensional configuration of the system derived when the axis and depths

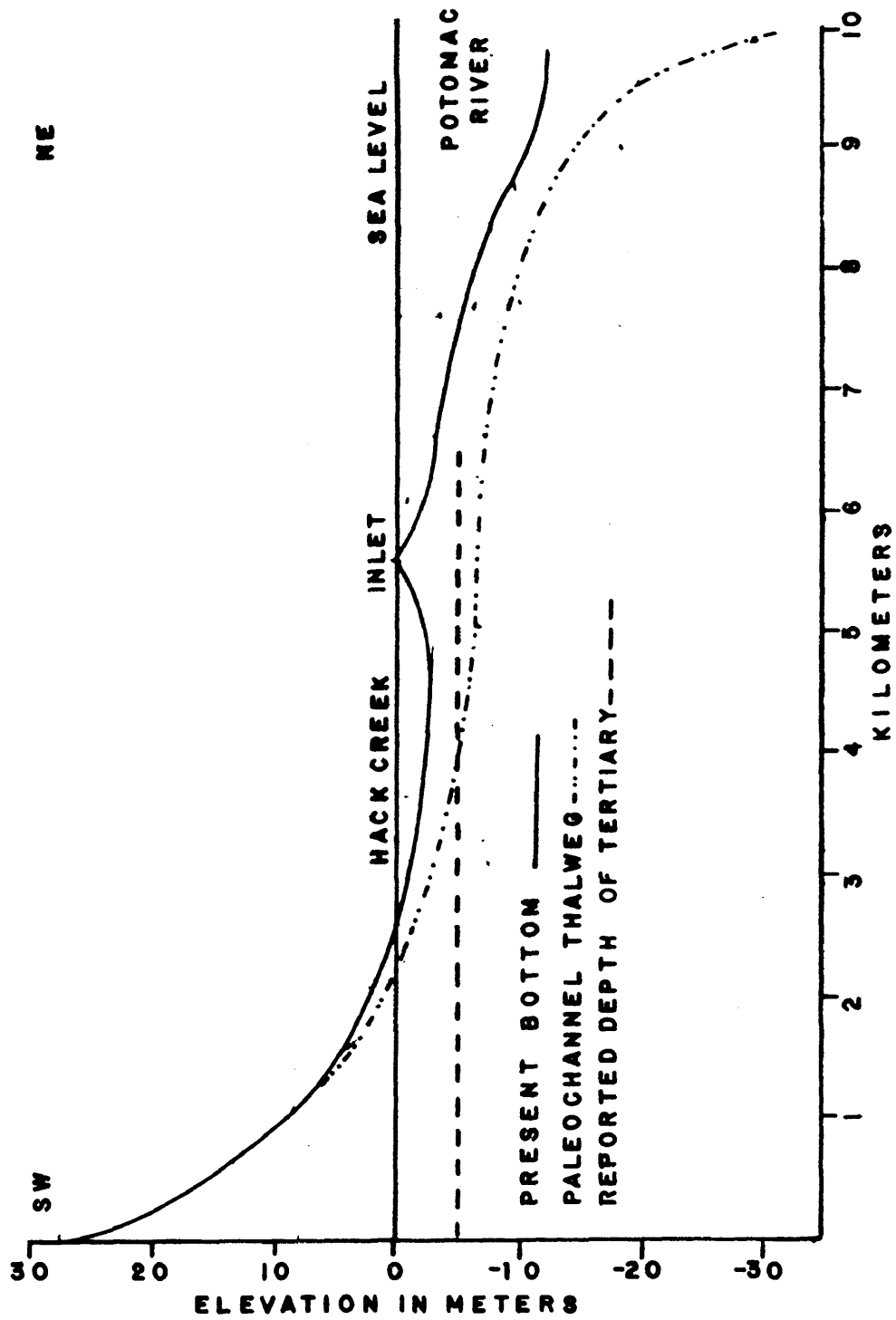


Figure 29. The slope of the present bottom and paleothalweg of Hack Creek and its paleochannel system.

of the paleochannel are plotted shows conclusively that these other systems are remnants of former branches in the dendritic drainage of the Hack Creek system (Figure 30). The present drainage basin area associated with Hack Creek is 906 hectares. At a lower stand of sea level, at -10 m (-33 ft) (Zellmer, 1979, and Finkelstein, personal communication), or prior to shoreline retreat, Hack Creek would have resembled the Little Wicomico River with a drainage basin area of 2500 hectares. Given sea level position and the rate of rise Hack Creek's drainage basin could be reduced an average of 0.4 hectares per year. This is strong evidence that the three types of drainage systems associated with the Chesapeake-Potomac estuary had the same origin. The three systems appear to represent different evolutionary phases in response to a marine transgression. Using this scheme, Hack Creek is in the middle stages of succession; while the small systems that were once a part of Hack Creek are in the terminal stage of the evolutionary process. Given a continuing rise in sea level, shoreline erosion may remove them all together (Bruun, 1962).

Sub-bottom lines normal to shore in the study area revealed the present Potomac River drainage and channel thalwegs are closely associated with the paleochannel described by Knebel et al. (1981). The cross sections of this study are 5 km (3.1 mi.) to the east of Knebel's study area and revealed two additional major paleochannels (Figure 31). The mid-river paleochannel, B, (4 km offshore) is filled with Holocene fill and appears to be the terminous of all the paleochannels associated with the Hack Creek system. If the ancestral Potomac River Valley is

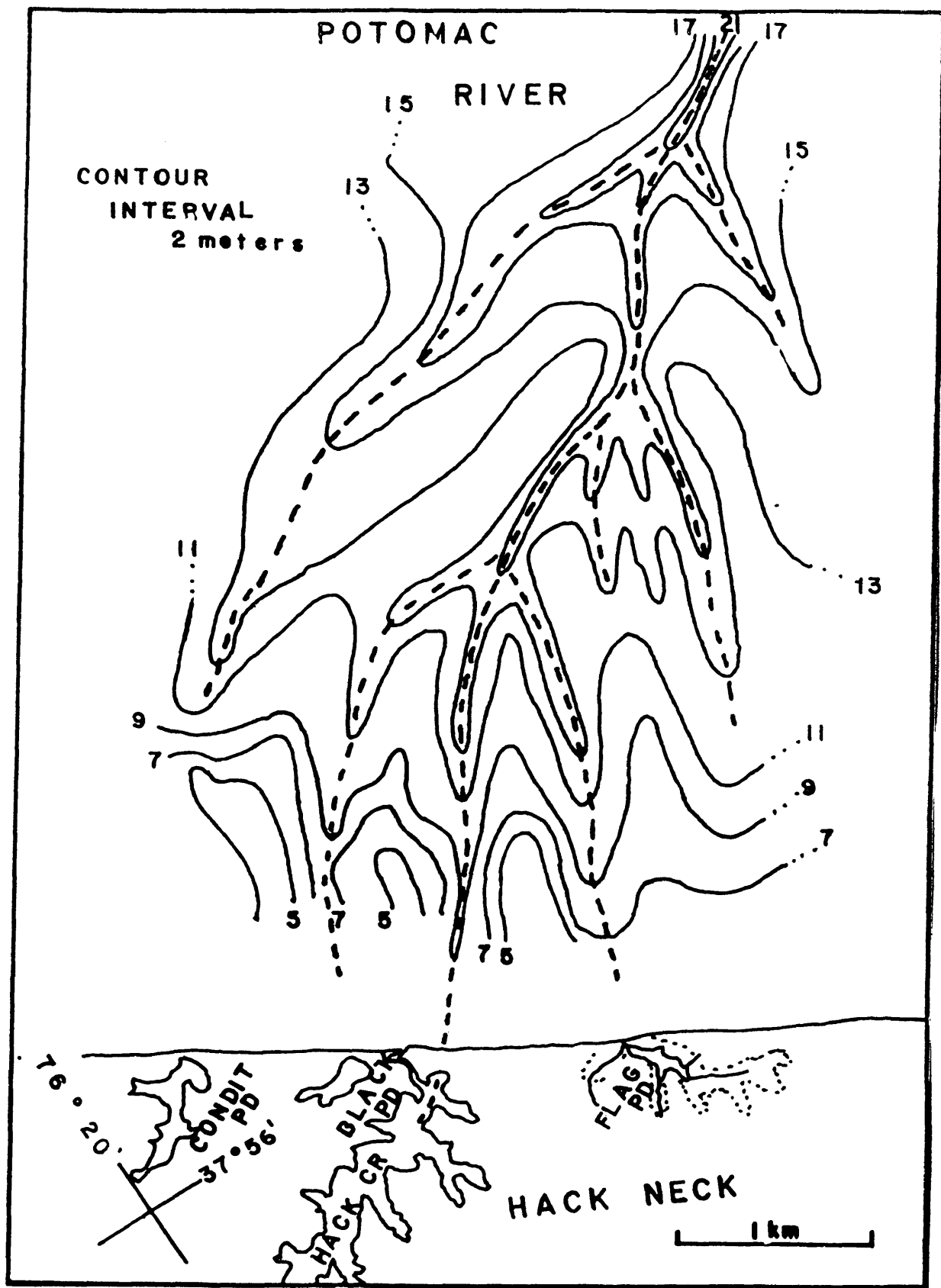


Figure 30. Depths of the paleochannels below MLW and paleochannel thalwegs of the Hack Creek system.

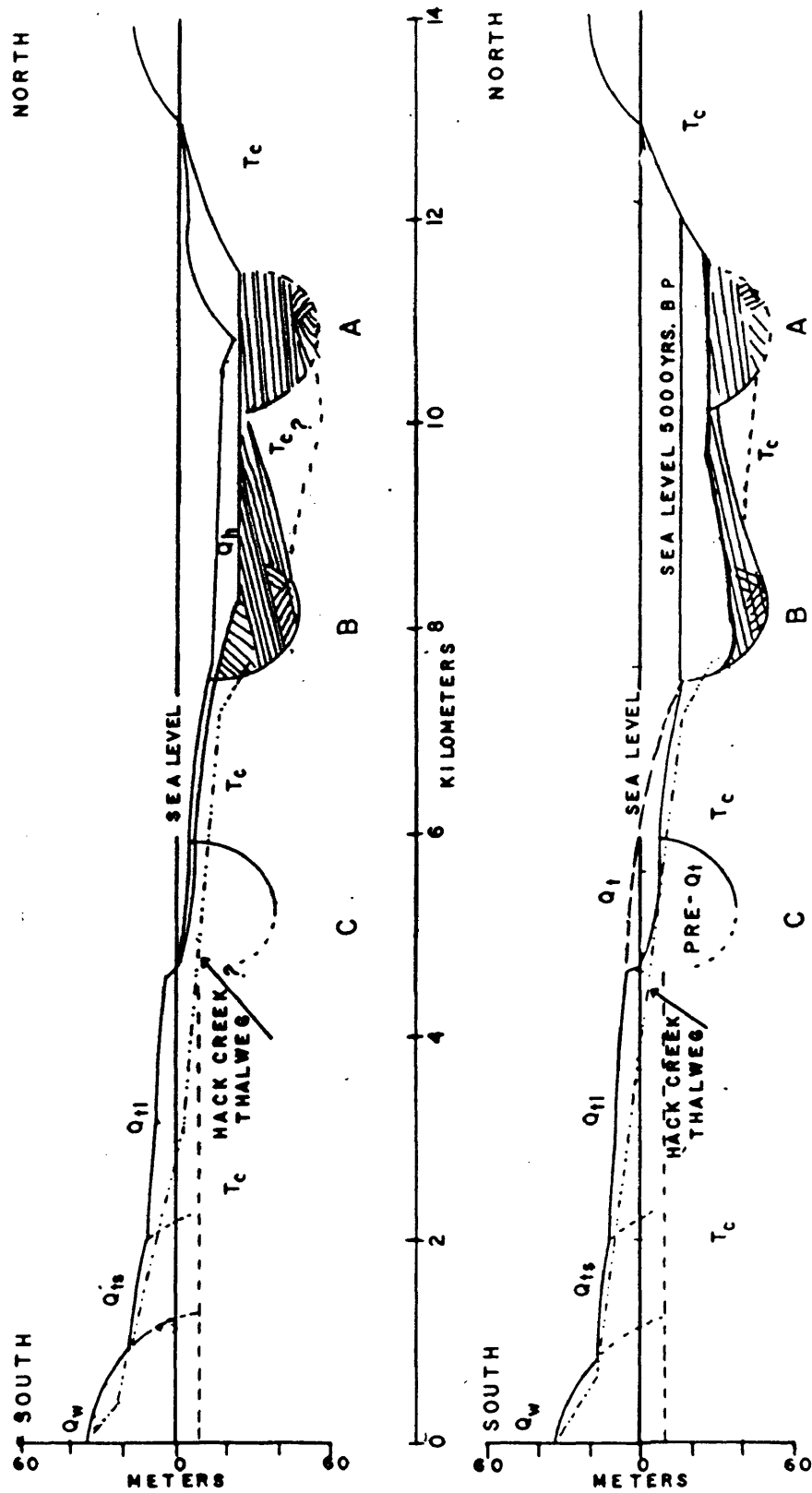


Figure 31. Schematic diagram of the shoreline formations and three Potomac River paleochannels (A, B and C) at present (top) and 5000 years BP (bottom).

the result of a single event, then as Knebel et al. (1981) so state, "this second channel would have to be either a meander or a bifurcation of the main paleochannel on the Maryland side of the estuary." Since both of these features have similar stratigraphic sequences in the seismic record, and do not exhibit any evidence of multiple events in the channel fill, it is probable that they are the result of only the late Pleistocene-Holocene regression-transgression cycle. The third paleochannel, C, observed in the seismic cross sections is located beneath the sediments of the shoreline flats and transitional slope. Vibracores in these units delineate the upper 1 to 2 meters (3.3 to 6.6 ft) of sediment to be a coarse grained, pebbly sand which appears to be a lag deposit derived from the mass wastage of an eroding shoreline (Peebles, 1984). Vibracore samples taken in the paleochannels exhibited a fining upward sequence consisting of a coarse basal lag of fluvial origin covered with organic material, a marsh or peat deposit grading into estuarine sand, silts, and clays. The same fining upward sequence was found inside the inlet and upstream on Hack Creek. Core samples collected outside of paleochannels indicated the surface material was deposited directly on Tertiary sediments. The rate of shoreline retreat for the study area is approximately 0.6 m per year (Rosen, 1976). Since the deep paleochannel is less than 1 km offshore, the sea level curve of Finkelstein (personal communication) indicates it could have been covered by the fastland formations and its associated drainage as recently as 5000 years BP (Figure 30). This assumes constant erosion rates of older deposits and the displacement of this material offshore

(Bruun, 1969) or along shore to form spits and bars. Because the Lynnhaven Member of the Tabb Formation presumably overlies paleochannel C, by superposition the third paleochannel would be older than the shoreline sediments, thus be pre-Lynnhaven and older than the other two paleochannels of the Potomac River. Due to the axial depth (-40 m) of paleochannel C (Figure 32) and orientation of the channel axis (Figure 33), it may be associated with the deltaic features reported by Carron (1979) to the southeast of Smith Point (Figures 34 and 35).

Most of the deep paleochannels of the Potomac and the deeper parts of the Hack Creek paleochannels incise the Chesapeake Group. The exception is where the Hack Creek paleochannels cross the nearshore paleochannel and the emergent Pleistocene units. However, since the Hack Creek system incises the Tertiary on both sides of this paleochannel; it is evident the two systems could not be of the same age.

Hack Creek's paleochannels indicate only one episode of stream valley cutting. The terminous of the Hack Creek system is a paleochannel of the Potomac River which displays no internal channels within the valley fill and the absence of gravel deposits above the basal stratum (Knebel et al., 1981). The cores of the Hack Creek paleochannels display only one fining upward sequence (transgression). Undoubtedly the present Hack Creek sub-estuary and its associated paleochannel system represents only one transgressive-regressive sequence. The age of this sequence would have to be late Pleistocene and Holocene.

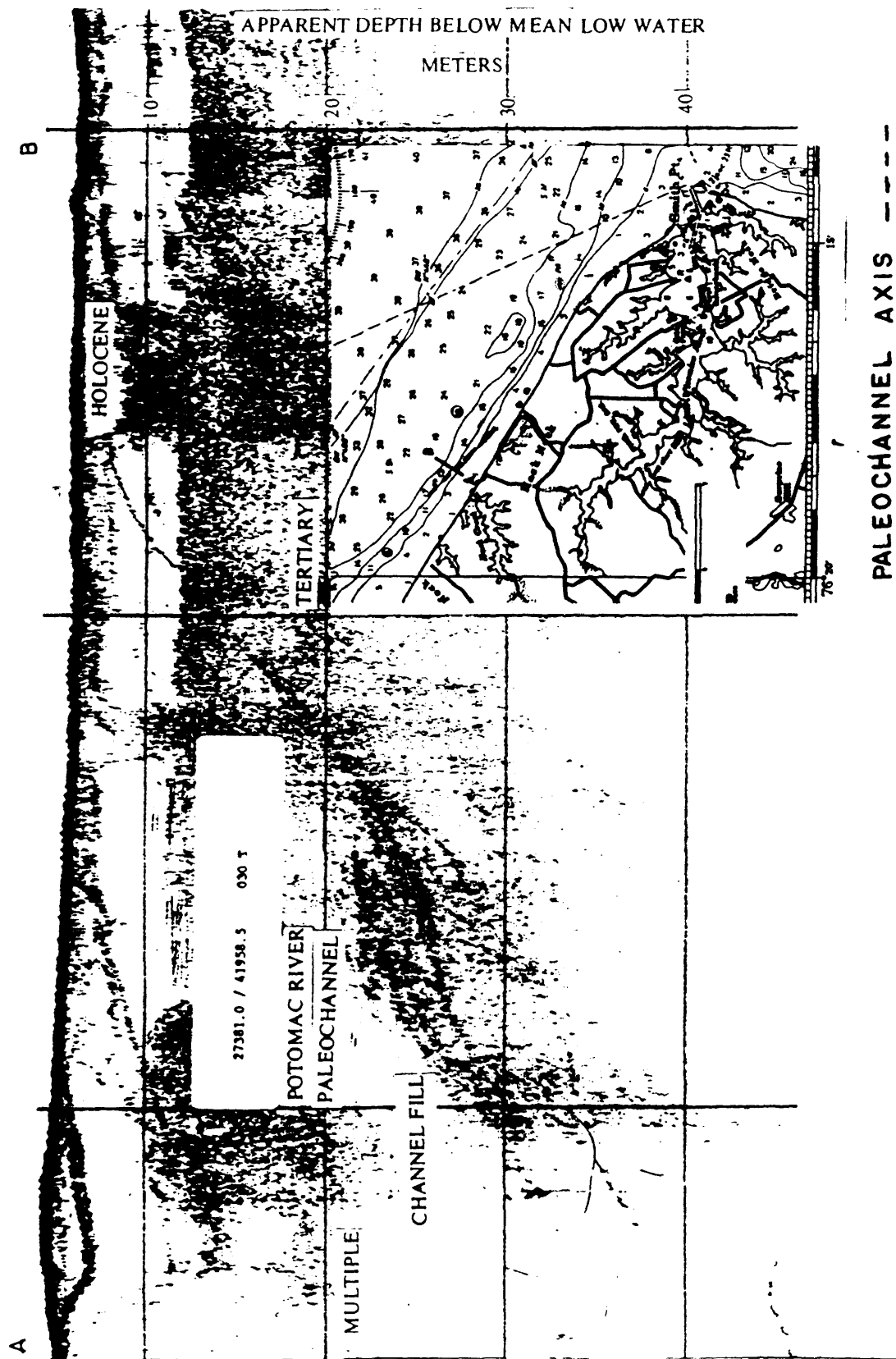


Figure 32. Paleochannel C having an axial depth of 40 m.

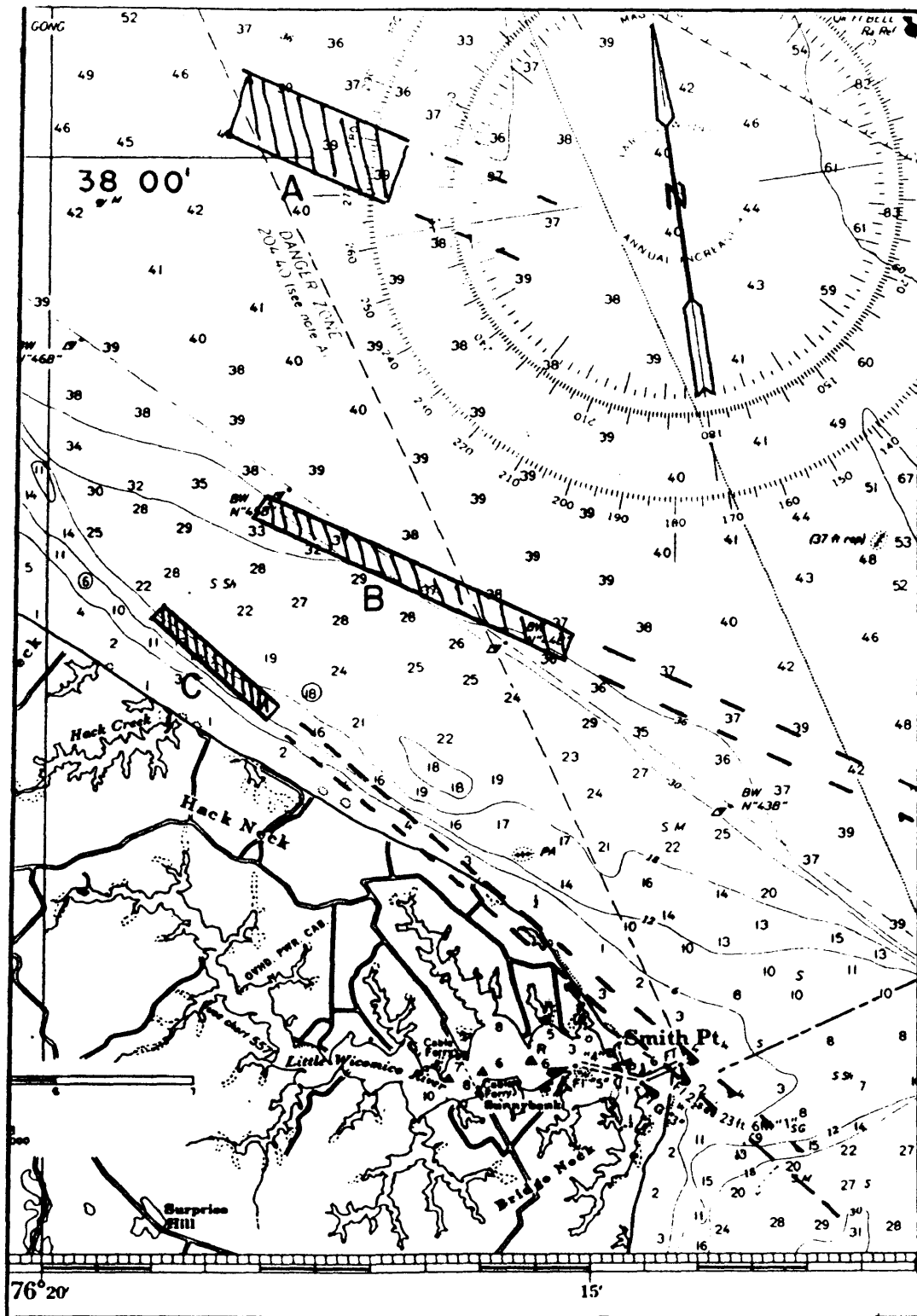


Figure 33. Location and axis of the three paleochannels of the Potomac River near Hack Creek.

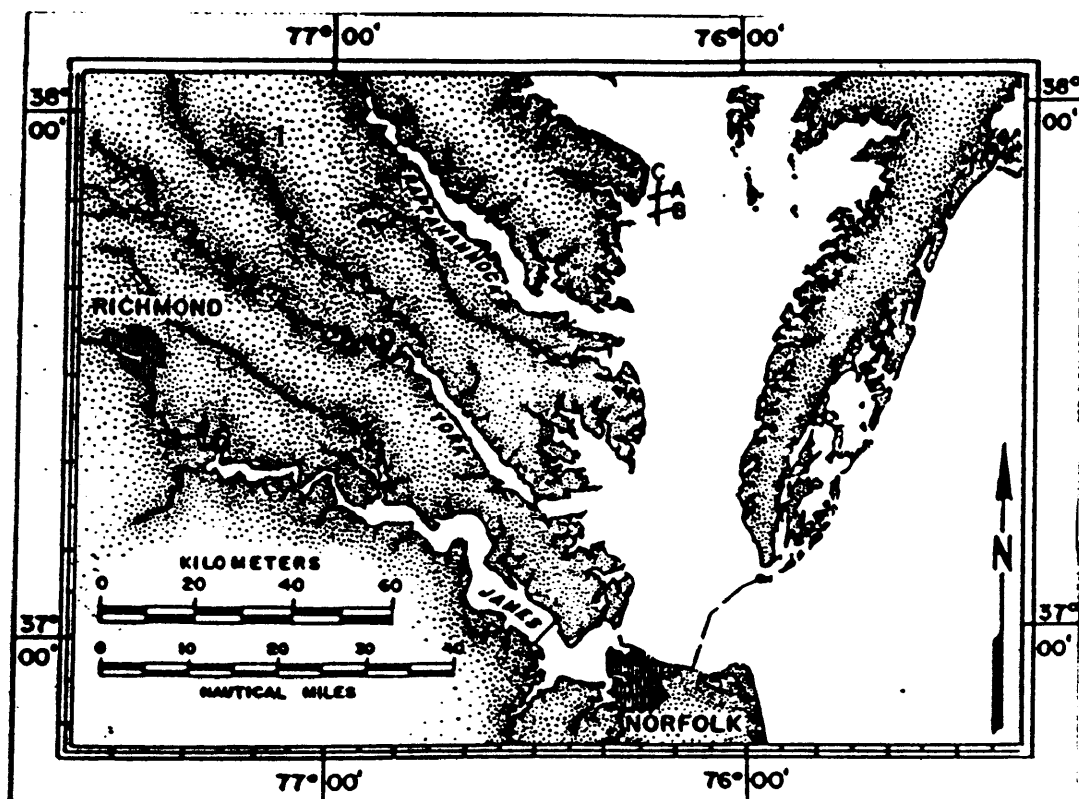


Figure 34. Sub-bottom seismic reflection locations at Smith Point, Virginia (after Carron, 1979).

APPARENT DEPTH BELOW MEAN LOW WATER

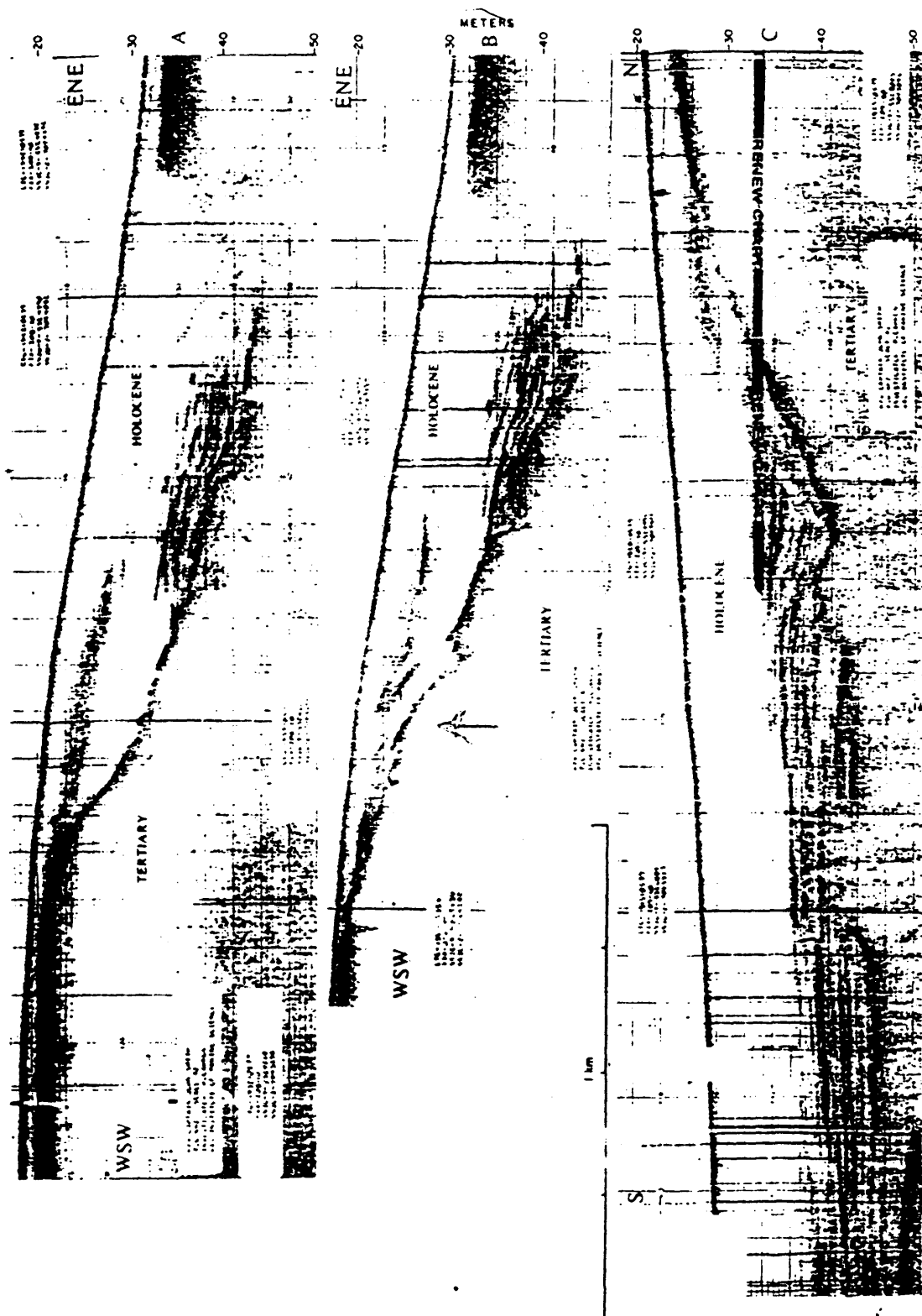


Figure 35. Sub-bottom seismic reflection records at Smith Point, Virginia (after Carron, 1979).

CONCLUSIONS

Seismic reflection data and geomorphic and stratigraphic evidence indicate that a complex paleochannel system exists in the sub-bottom of the Potomac River nearshore adjacent to the present Hack Creek inlet-basin system. This system is evidence of at least one cycle of regression-transgression in the Potomac River Basin. The Hack Creek paleochannels provides the link for a contiguous drainage system between the upland fluvial drainage and the Potomac River paleochannel more than 4 km offshore. This channel complex interconnects Hack Creek and three smaller creek systems- Flag Pond to the east and both Black Pond and Condit Pond to the west. The paleochannels from each of the four systems terminates in one common paleochannel. The paleochannels of Hack Creek and nearby Potomac River system are incised into Tertiary sediments of the Chesapeake Group. The contact between Tertiary and younger sediments is a strong reflector in the seismic data. This horizon allows discrimination of the stratigraphy and determination of thickness of younger sequences in seismic records, cores and borings, such as water well logs. Older Tertiary formations are not important to this study. Vibracore samples taken within the paleochannels exhibit both the vertical and lateral succession of sediment facies expected in a marine transgression. The same facies succession is recognizable in cores from the channel axis of Hack Creek and the adjacent systems.

Stream gradients calculated for the Hack Creek paleochannels are the same order of magnitude as those measured in the Hack Creek drainage basin. This is evidence that the system is fluvial in origin and that it was also a small tributary to the ancestral Potomac River.

The Holocene transgression provided a mechanism for wave action to mold the shore by beach and cliff erosion along the flanks of Pleistocene Potomac River Valley. Net result of shoreline erosion was the truncation of sub-estuaries and the drowning and destruction of inlets, marshes and tidal channels. Shoreline erosion of the stratigraphic units into which the Hack Creek system is incised provided lag deposits and buried any evidence of the Hack Creek system in the resultant nearshore flats.

Seismic profiles show a lack of multiple sub-bottom channels and an absence of internal channels within the valley fill material of both the Hack Creek and offshore Potomac River paleochannels. The Potomac River paleochannel found near the Virginia shoreline is partially capped with a lag deposit derived from shoreline erosion. This is evidence that when Hack Creek was a larger system this paleochannel would have been buried by at least one of the formations that now make up the fastlands. The fastlands on the Virginia side of the Potomac River are underlain by a succession of Pleistocene formations. These formations are transgressive-regressive sequences represented by stranded relict shorelines (scarps) and associated depositional surfaces (terraces) that exhibit a fining upward sediment sequence. These sequences represent multiple oscillations of sea level during the Pleistocene. The Hack

Creek paleochannels incise the Tertiary sediment on both sides of this nearshore buried Potomac River paleochannel. There is no evidence in the seismic record that any of the Hack Creek paleochannels terminated in this southerly Potomac River paleochannel. All the data indicate that the Hack Creek system, as it exists today, was never associated with this nearshore Potomac River paleochannel, but with the paleochannel 4 km offshore. If a minor fluvial drainage system was present during the time of this southerly Potomac River channel's activity, the last transgressive-regressive cycle represented in the shoreline, the Tabb Formation, could have reworked the sedimentary record in the process of burying the paleochannel. The stratigraphic evidence indicates the southerly (nearshore) paleochannel of the Potomac River to be pre-Tabb in age.

Hack Creek and its associated system of paleochannels have geomorphic and stratigraphic features that fit well with the model for Holocene drainage systems. Development of the Hack Creek drainage system was initiated by the early Pleistocene regression of sea level. Fluctuation of the Pleistocene sea continuously altered the drainage basin area of Hack Creek. Fluvial incision continued in areas not reoccupied by the sea and eroded sediments from the previous transgressive cycle. During regressive cycles the Hack Creek system increased in size and stream competency, affording deeper incisement of stratigraphic units. The late Pleistocene (Wisconsinan) regression of sea level resulted in maximum aerial exposure of sediments allowing the formation of a drainage basin nearly three times that of the present day

drainage basin (Figure 36). The ensuing late Pleistocene and Holocene rise of sea level reduced stream gradients, consequently decreasing the competency of Hack Creek. The system changed from a erosional to a depositional phase. The sequence of vertical and lateral deposits associated with marine transgression began to accumulate. The fluvial phase of Hack Creek evolved into an estuarine tributary of the Potomac River Estuary. Shoreline erosion truncated the Hack Creek system and buried the deeper channels beneath the transitional slope and shoreline flats of the Potomac. The larger branches of Hack Creek dendritic drainage were dismembered and isolated to become independent systems. The reduced drainage basin size of the now independent systems and the main stem of Hack Creek caused Hack Creek to evolve into an inlet-basin type drainage system. Hack Creek at present represents this type of drainage. The subaerial tributaries of Hack Creek have evolved into the third, or terminal type of drainage- the ephemeral pond. The continued rise in sea level and/or shoreline erosion will remove the present ponds from the local drainage basin and produce new ephemeral pond systems from other branches of Hack Creek. Once the Hack Creek inlet-basin system is sufficiently reduced in size, it too will evolve into a ephemeral type drainage system.

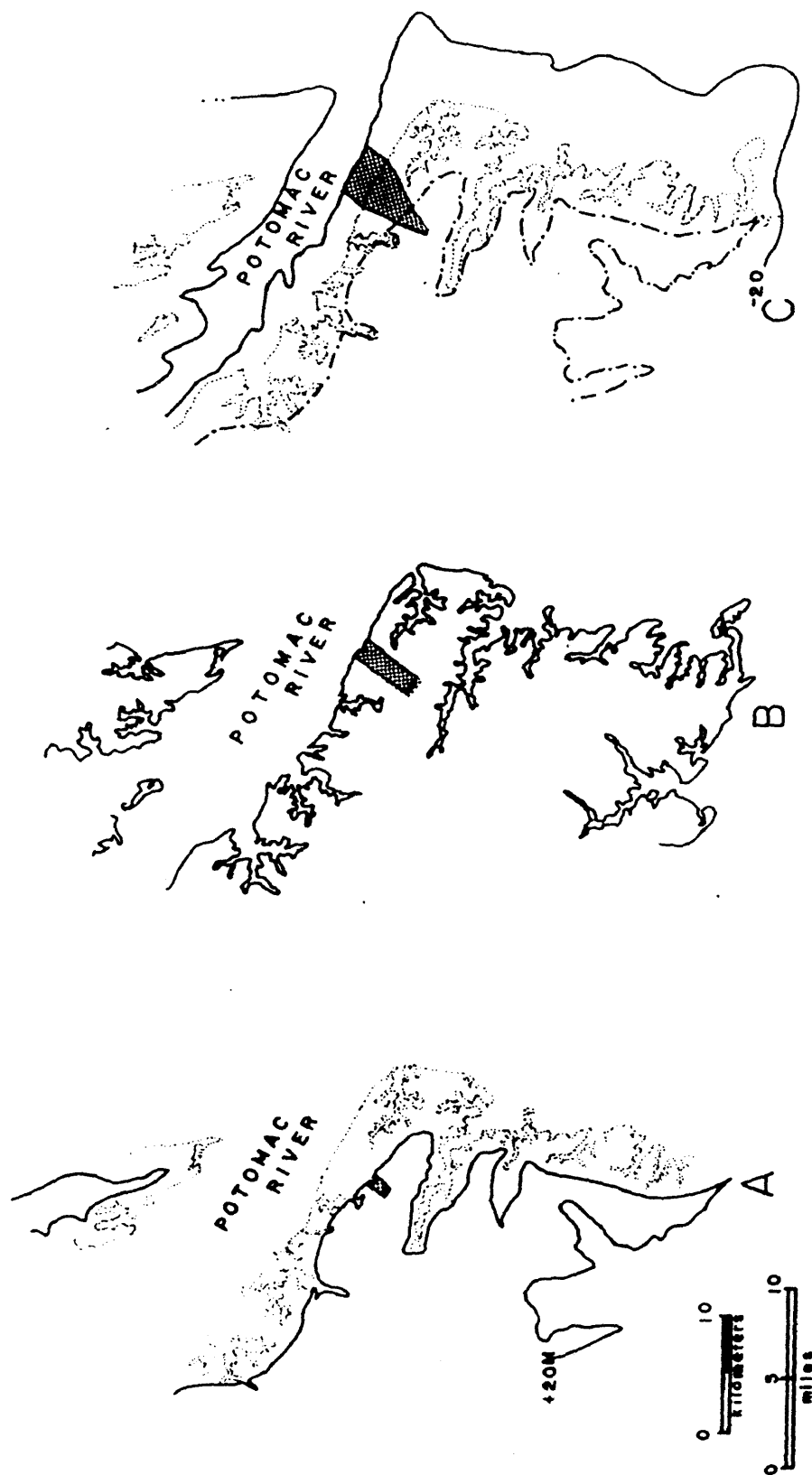


Figure 36. Drainage area of Hack Creek at
 A) sea level + 20 m
 B) sea level at present
 C) sea level at - 20 m

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